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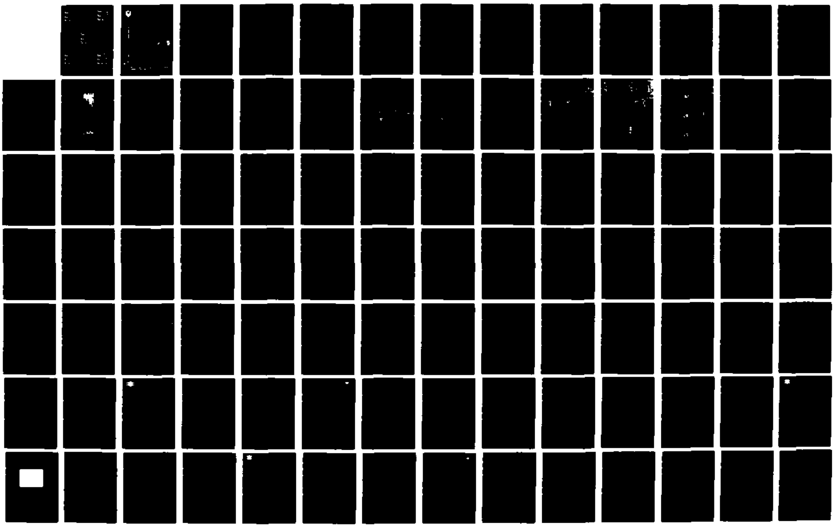

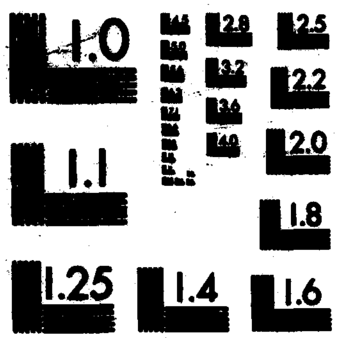

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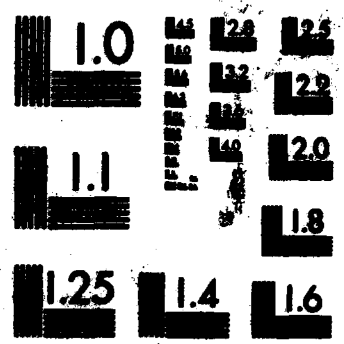

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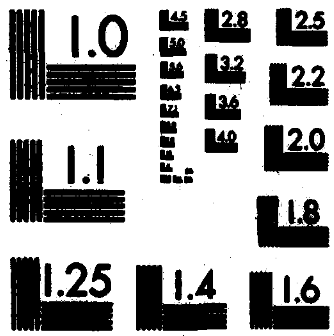

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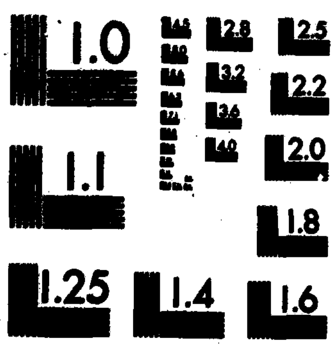

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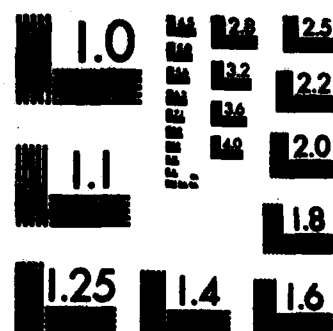

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Research and Development Technical Report

DELET-TR-79-0260-F

PRIMARY LITHIUM ORGANIC ELECTROLYTE BATTERY
BA-5588 ( )/U

M.G. ROSANSKY

POWER CONVERSION, INC.
495 BOULEVARD, ELMWOOD PARK, N.J. 07407

JULY 1982

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Current Density, Fuse, Forced Reverse Discharge.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This program concerns the development, fabrication and evaluation of a Lithium-Organic Electrolyte Battery designated BA 5588 ( )/U which incorporates five (5) series connected, hermetically sealed cells housed in a plastic case. Significant effort was directed towards cell optimization through controlled experimentation and evaluation of various design parameters. Demonstration of the effectiveness of the

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finalized design was accomplished by the performance of various electrical and abuse tests which included environmental exposure, prolonged thermal storage, electrical discharge under various thermal profiles, short circuit and discharge to zero volts as well as forced discharge. The resulting evaluation demonstrated the batteries ability to operate safely under all of the specified abusive environments and provide 100% of the specified service life requirements.

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1. OBJECTIVE

The subject Final Technical Report concerns the development, fabrication and testing of Battery BA-5588 ( )/U in accordance with the performance and safety requirements as defined in the Technical Guidelines for Primary Lithium Organic Electrolyte Battery BA-5588 ( )/U dated 3 February 1978. Our primary concern has been the fabrication of the subject batteries in conformance with these guidelines and the demonstration of effective safety mechanisms and hermetic cell designs to insure non-hazardous battery operation under all specified conditions of storage, use and operation. Such consideration included the safety vent design, cell electrode configuration cell case design and configuration and electrical fuse protection within the battery.

2. REFERENCE DOCUMENTS

2.1 Contract No. DAAK20-79-C-0260, BA 5588 ( )/U dated 16 April 1979.

2.2 Technical Guidelines for Primary Lithium Organic Electrolyte Battery BA 5588 ( )/U dated 3 February 1978.

2.3 Environmental Test Reports Nos. ST-2220 and ST-2398-00C, Stanford Technology Corporation dated February 5, 1980 and May 29, 1980, respectively.

2.4 MIL-STD-810C Environmental Test Methods, 10 March 1975.

3. BATTERY ENVELOPE

The BA-5588 ( )/U battery was designed in accordance with the envelope dimensions, and polarity as specified in Figure 1. Five cells, which were designed to fit into the prescribed envelope, were connected in series to provide the required output voltage. The basic design considerations were as follows:

- Dimensional Configuration and Weight Limitation
- Operational Voltage Limits
- Battery Case Design and Material Selection
- Environmental/Safety Requirements
- Electrical Fuse Protection
- Fabrication and Material Costs

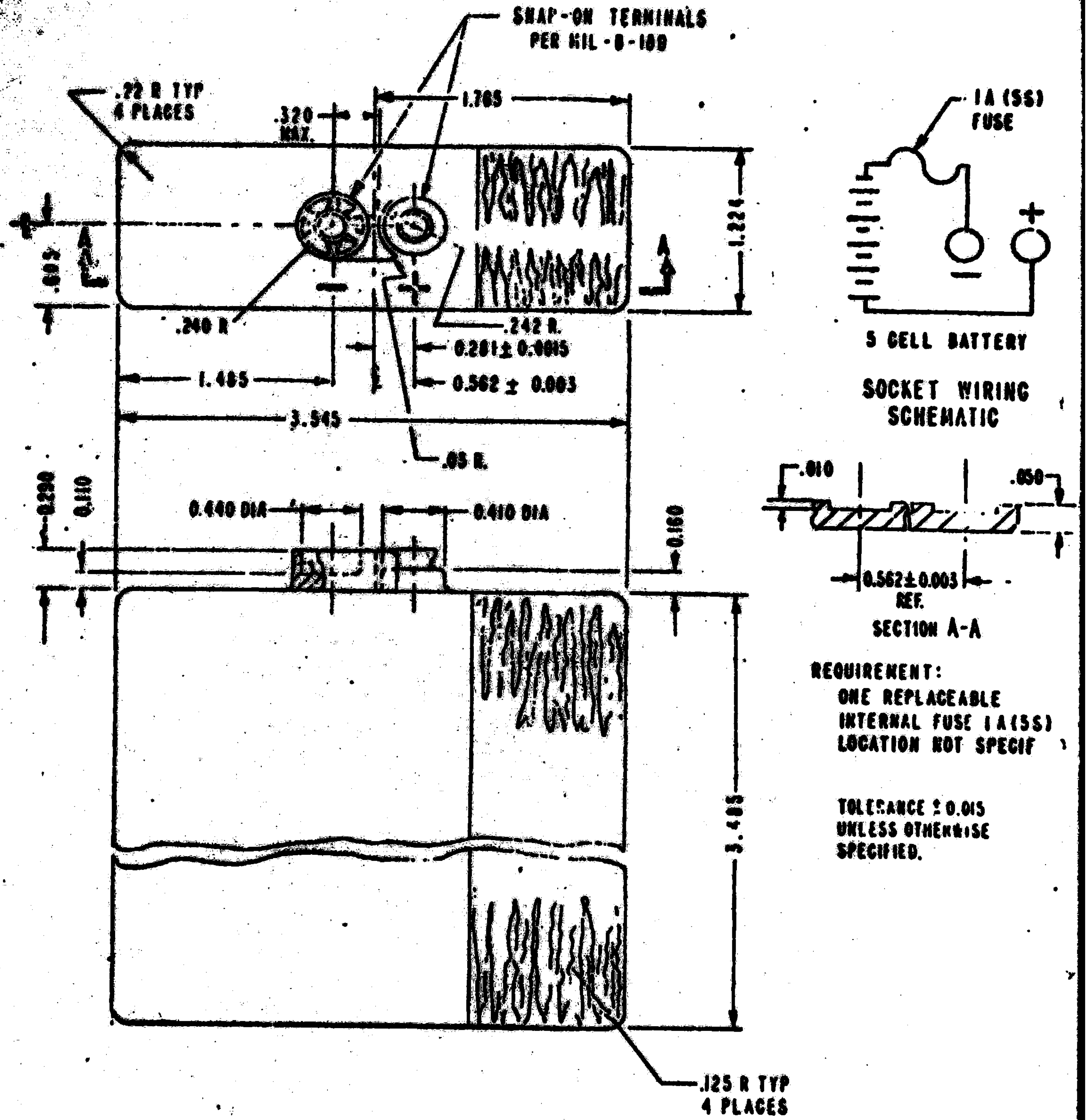


FIG. 1 PRIMARY LITHIUM ORGANIC ELECTROLYTE BATTERY BA5588( )/U

The battery's physical, electrical and performance requirements as delineated in the Technical Guideline for Primary Lithium Organic Electrolyte Battery BA-5588( )/U dated 3 February 1978 are as follows;

3.1 Physical Characteristics

Length (inch)	3.545 ± 0.015
Width (inch)	1.244 ± 0.015
Height (inch)	3.485 ± 0.015
Weight (lbs.)	0.75 maximum
Volume (cubic Inches)	15.1

3.2 Electrical Characteristics

Operating Voltage Limits (volts)	12 to 15
Current (maximum)	.34 amps pulsed
Capacity	
@ +160°F	2.87 amp-hrs.
@ +130°F	2.87 amp-hrs.
@ +70°F	2.87 amp-hrs.
@ -40°F	.96 amp-hrs.
Energy (watt-hrs)	39.0
Energy Density (watt-hrs/lb)	52.1
Volumetric Energy Density (watt-hrs/in^3)	2.6

3.3 Performance Requirements

The discharged performance requirements are as follows:

3.3.1 Discharge Profile

The battery shall be pulse discharged through 40 ohms for one (1) minute followed by 207 ohms for nine (9) minutes repeated continuously to zero voltage.

The cell shall be pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to zero voltage.

3.3.2 Voltage Delay

Upon start of discharge under any specified test condition, closed circuit voltage below 12 volts (2.4 volts per cell) shall not exceed 0.1 second duration.

3.3.3 End Voltage

During the course of any battery discharge test, the time at which the output voltage falls below 12 volts is considered for determination of service life.

During the course of any cell discharge test, the time at which the output voltage falls below 2.4 volts is considered for determination of service life.

3.3.4 Service Requirements

The battery and cells are required to deliver the following minimum service to the applicable end voltage under the specified discharge profile for each of the following conditions after exposure to any or all environments or storage conditions:

(a) 30 hours service under discharge at $+75 \pm 7^{0}F$.

(b) 30 hours service under discharge at $+130 \pm 3^{0}F$ following stabilization of the battery for a minimum of 8 hours at $130 \pm 3^{0}F$.

(c) 30 hours service under discharge at $+160 \pm 3^{0}F$ following stabilization of the battery for a minimum of 8 hours at $160 \pm 3^{0}F$.

(d) 10 hours service under discharge at $-40 \pm 3^{0}F$ following stabilization of the battery for a minimum of 8 hours at $-40 \pm 3^{0}F$.

3.3.5 Environmental Tests

Cells and batteries shall deliver the specified minimum service requirements after exposure to the following environmental tests:

Temperature Shock - In accordance with MIL-STD-810C, Method 503.1 for five cycles (do not discharge during or immediately after test).

Shock - In accordance with MIL-STD-810C, Method 516.2 Procedure I, Curve 516.2-2 for ground equipment. (Do not discharge during or immediately after test.)

Vibration - In accordance with MIL-STD-810C Method 514.2 Equipment Category (h), Procedure X and XI, Figure 514.2-7, Table 514.2-VII. (Do not operate during or after test.)

Altitude - In accordance with MIL-STD-810B, Method 500.1 Procedure I. (omit Step 4; do not discharge during or immediately after test).

4. CELL DESIGN CONFIGURATION

4.1 Cell Selection

Several hermetic cell designs were evaluated under this program in an effort to achieve all specified performance and safety requirements. Various electrode configurations and geometries were evaluated under the BA 5588 ( )/U discharge load profile. Parameters investigated included the following:

- Electrode Surface Area
- Lithium/SO_2 Ratio
- Cathode Utilization Efficiency
- Cell Construction

Various cell configurations were evaluated and analyzed during the Preliminary Design Cell Fabrication Phase and are discussed in paragraph 6 of this report.

The hermetically sealed lithium sulfur dioxide described below, was utilized to fabricate the required BA 5588 ( )/U batteries.

4.2 Cell Design Considerations

The cell design, as illustrated in Figure 2, was defined in an effort to meet or exceed all performance, safety and environmental requirements. Basic design considerations included the following:

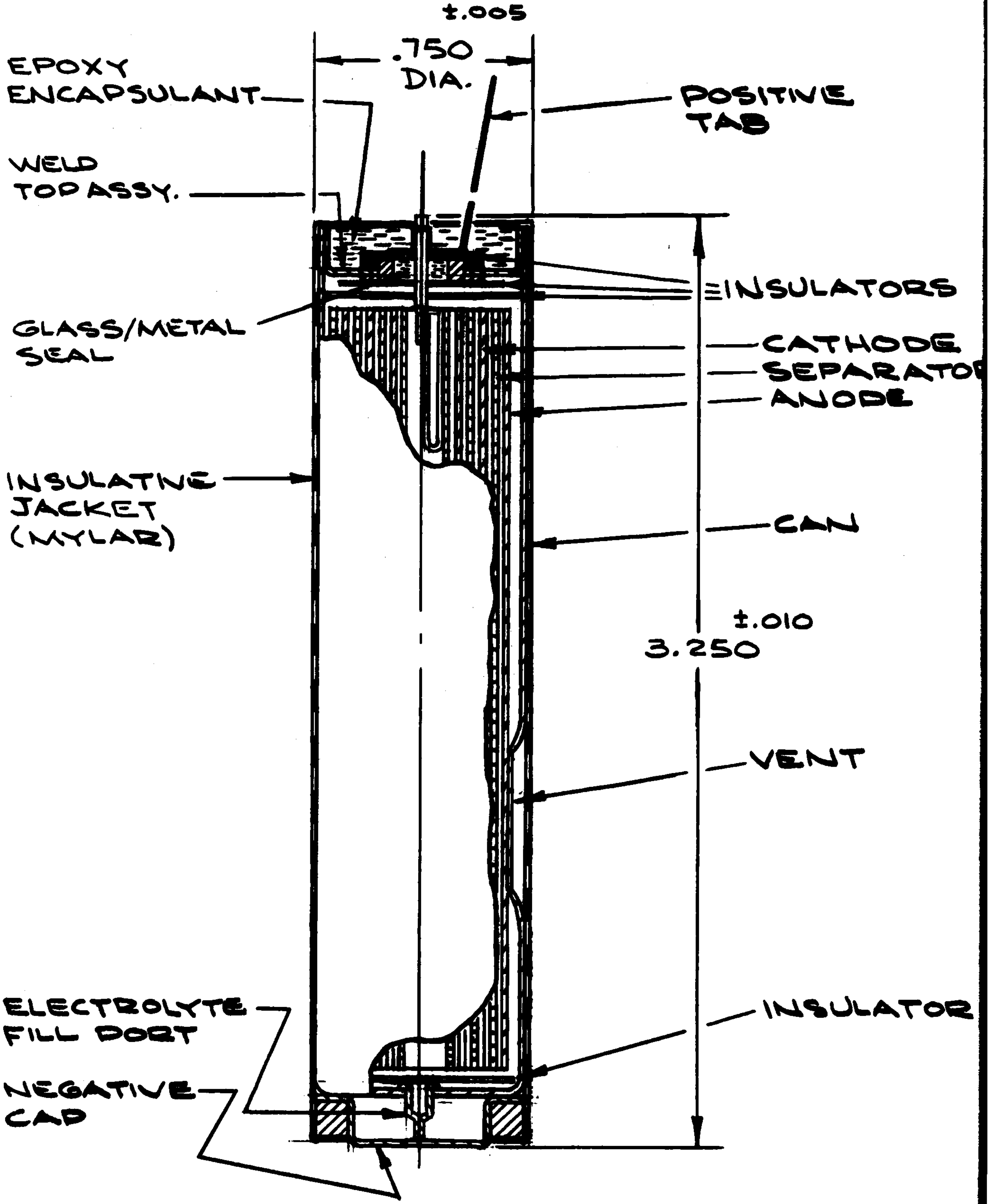


Figure 2

BA-5588/U CELL
CROSS SECTION

- Discharge Capacity and Rate
- Minimal Current Density Levels
- Operational Voltage Limits
- Voltage Delay Requirements
- Dimensional Configuration and Weight Limitations
- Environmental/Safety Requirements
- Fabrication and Material Costs

4.2.1 Physical Characteristics

Diameter:	0.750	inch
Length:	3.25	inch
Weight:	44.5	grams
Volume:	23.5	cc

4.2.2 Electrode Configuration

The high rate cell design utilized in this battery required maximum utilization of available internal cell volume in order to achieve the specified capacity levels and to maximize start-up voltages, especially after thirty (30) days storage at +160°F. The electrode design was based upon maintaining a balanced stoichiometric proportion of the active components, optimizing electrode utilization efficiency and minimal current density levels. The electrode characteristics were as follows:

Anode

Active Length (inch)	9.0
Width (inch)	2.5
Thickness (inch)	.006
Weight (grams)	1.18
Theoretical Capacity (amp-hrs)	4.56

Cathode

Active Length (inch)	9.0
Width (inch)	2.5
Thickness (inch)	.026
Porosity (%)	85

Separator

Type	Microporous Polypropylene
Length (inch)	24
Width (inch)	2.75
Thickness (inch)	.001
Porosity (%)	45

Electrolyte

Weight (grams)	15.5
Theoretical Capacity (amp-hrs)	4.48

Electrical Characteristics

Electrode Surface Area (cm^2)	290
Current Density (ma/cm^2)	
8 ohms	1.21
41.4 ohms	0.23
Li/SO_2 Ratio	1.02

4.3 Cell Construction

The cell was constructed as follows to insure conformance to all dimensional and performance requirements:

The cell case consists of a nickel plated CRS alloy enclosure. A flanged nickel plated CRS fill port is welded to the can base to permit subsequent dispensing of electrolyte within the cell. The can base is configured to permit installation of a welded contact button which protects the fill port closure and serves as the negative electrical connection. A mechanical safety vent mechanism is formed within the side wall of the cell case (see paragraph 4.4).

The top structure consists of a CRS shell shaped as shown so as to provide suitable surfaces for peripheral welding.

The glass seal assembly consists of solid tantalum terminal which is hermetically fused to a CRS eyelet and subsequently projection welded to the top shell structure The terminal is coined at one end to provide a suitable contact surface for electrical connection of the internal cathode tab.

The electrode core consists of a spirally wound anode and cathode assembly which are separated by an insulative microporous polypropylene barrier; a configuration which maximizes electrode surface area. The assembled core is inserted within the cell case and appropriate electrical connections are made prior to installation of the top structure.

The assembled cell is hermetically sealed along the case periphery using an arc welding process. Electrolyte is subsequently dispensed within the cell at which time hermetic closure of the fill port is accomplished.

4.4 Safety Vent Mechanism

Since the lithium/SO_2 electrochemical system utilizes a pressurized electrolyte, a pressure activated safety vent mechanism was used to exhaust over-pressurized electrolyte at a pre-determined temperature (equivalent to approximately 450 psi) to effect cell deactivation. The safety vent as shown in Figure 3, consists of a coined cross section located in the can wall and parallel to the center line; a configuration which occupies minimal internal volume. The coined structure is rolled radially inward during fabrication which accomplishes the following:

. Minimizes the bulging of the can outer diameter to conform to the required envelope dimensions during all required thermal environments.

. Provides a pivot configuration which minimizes tensile loading of the coined surface during normal cell storage and operating environments. The flexure joint is designed to invert at approximately 200 - 210°F at which point, the coined section is subjected to direct tensile loading due to the electrolyte vapor pressure within the cell. Such action provides greater control and reproducibility of the venting characteristics and permits a graduated release of electrolyte upon venting.

. Provides protection and isolation of the vent structure during cell/battery assembly and handling to prevent accidental vent rupture or damage.

5. BATTERY DESIGN CONFIGURATION

The BA-5588 ( )/U battery design configuration, as shown in Figure 4, consists of five (5) series connected cells, each cell being 0.75 inches in diameter by 3.25 inches long.

5.1 Battery Case

The battery case is fabricated from Borg Warner,

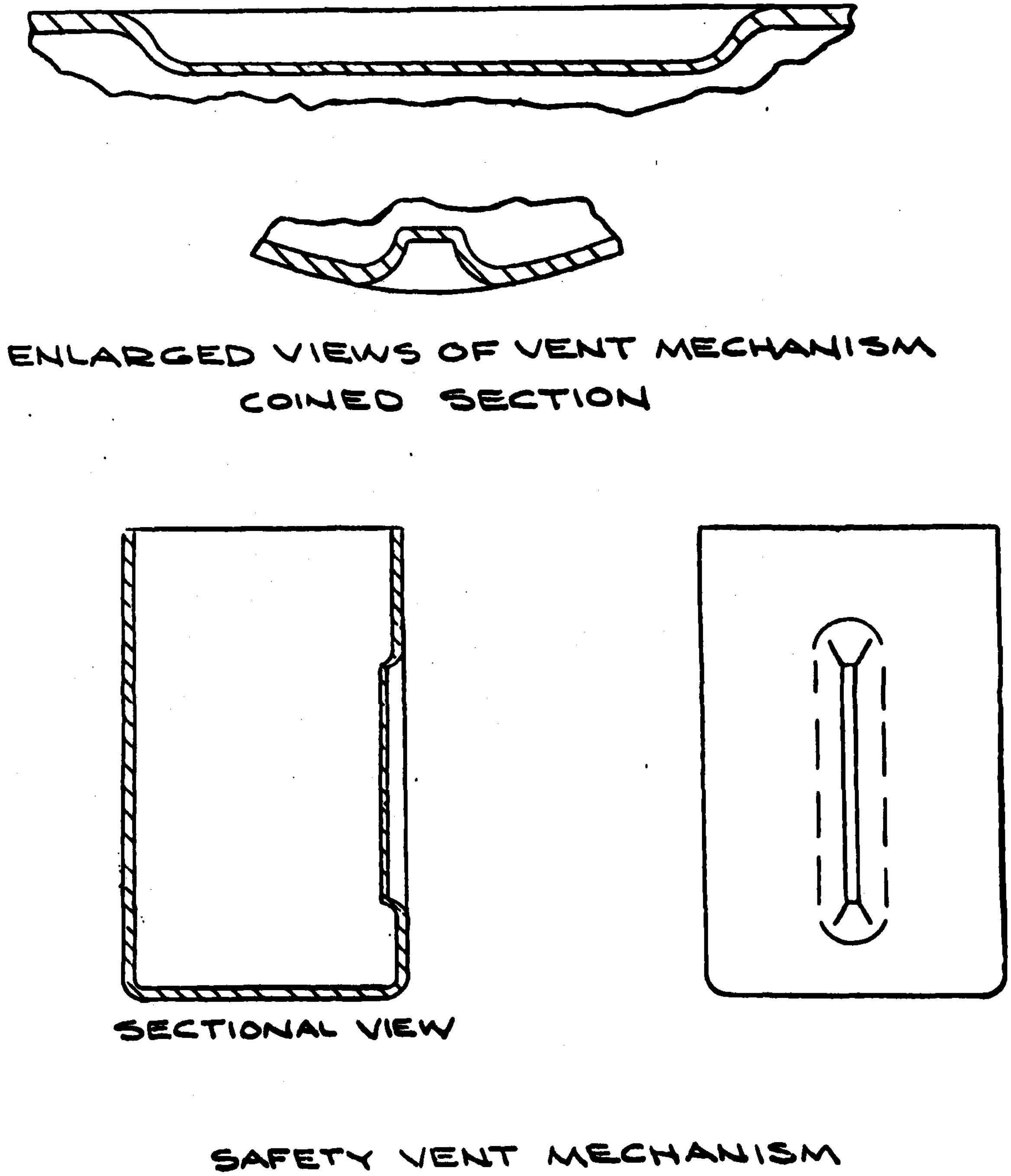

ENLARGED VIEWS OF VENT MECHANISM
COINED SECTION
SECTIONAL VIEW
SAFETY VENT MECHANISM

Figure 3

BATTERY ASSEMBLY

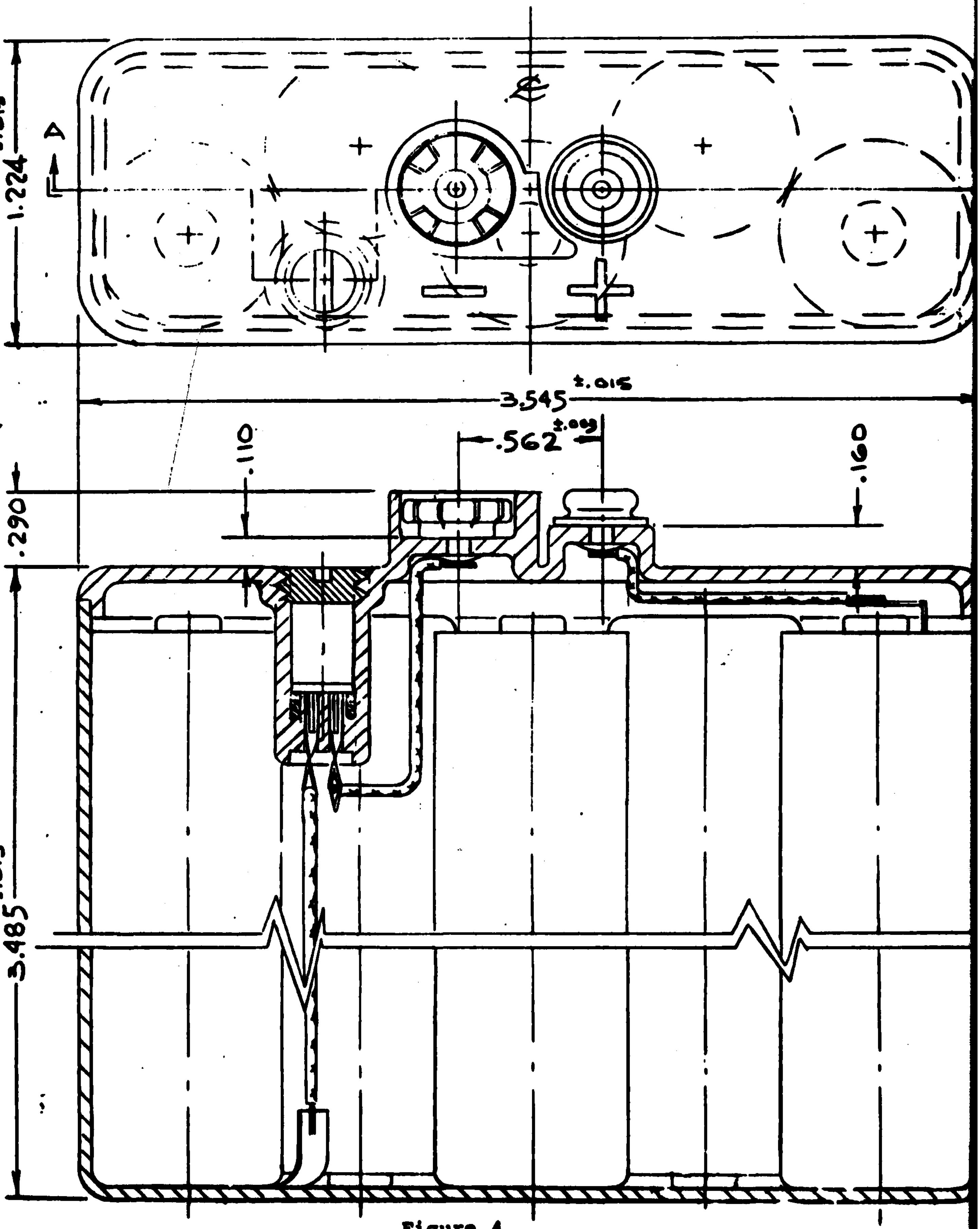


Figure 4

BATTERY ASSEMBLY

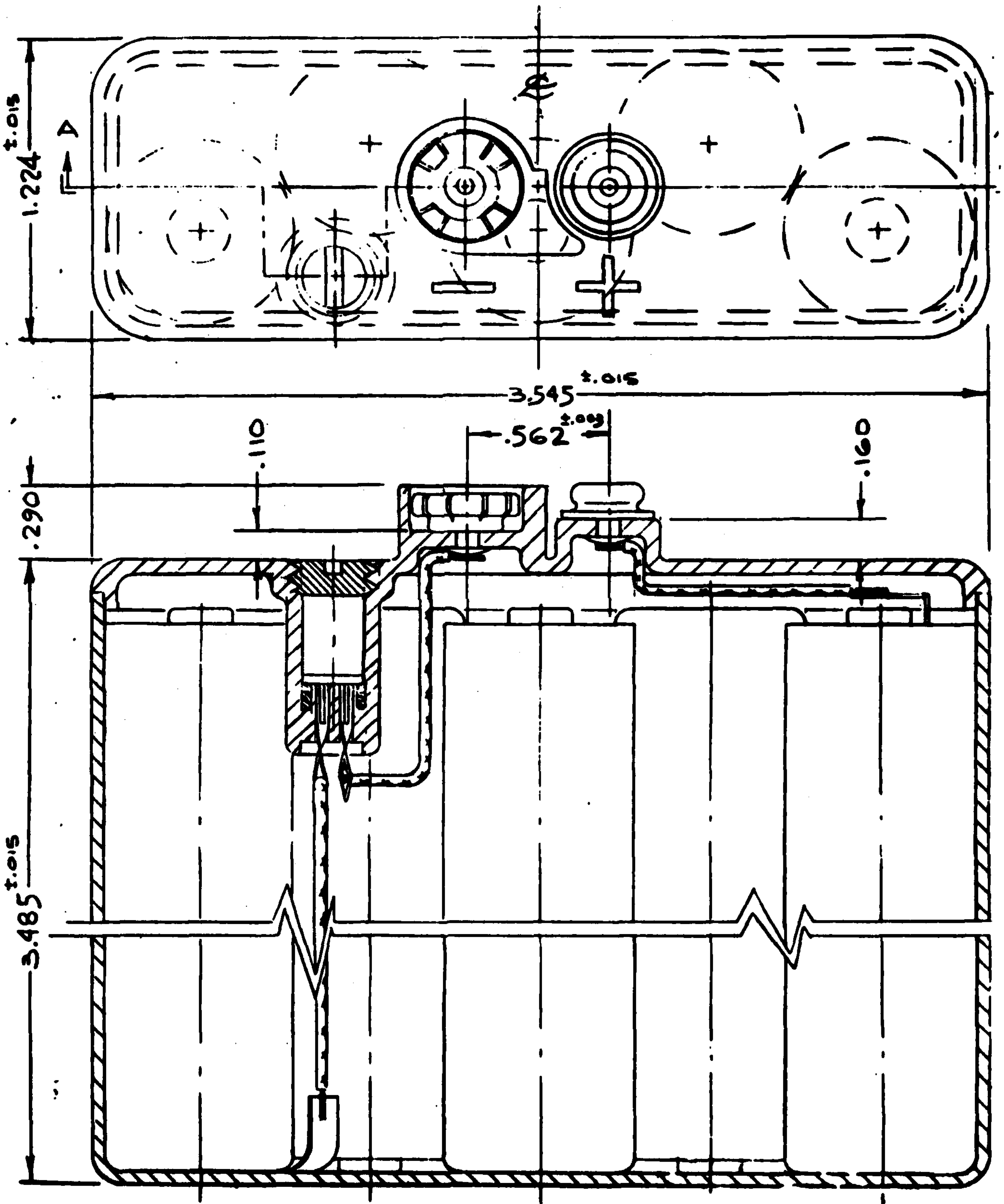


Figure 4

Cycolac KJW; and ABS flame retardant termoplastic material which has an Underwriters Laboratories Flame Class Rating of 94V - 0 at 0.058 "and 94-5V at 0.120". The case and case cover is shown in 5 and 6 respectively. Figure 7 is a drawing showing the battery label and marking configuration.

5.2 Electrical Fuse

The battery is electrically protected with a replaceable 1 ampere 5 second fuse located within the negative leg of the cell stack assembly. The fuse assembly consists of a Littelfuse 281001 plug-in picofuse. Verification of the electrical fuse characteristics was performed to determine the time required for fuse activation at various current levels as it relates to the five (5) second requirement of the Technical Guidelines. These characteristics have been graphically represented in Figure 8, "Fuse Time Current Characteristics".

5.3 Connector

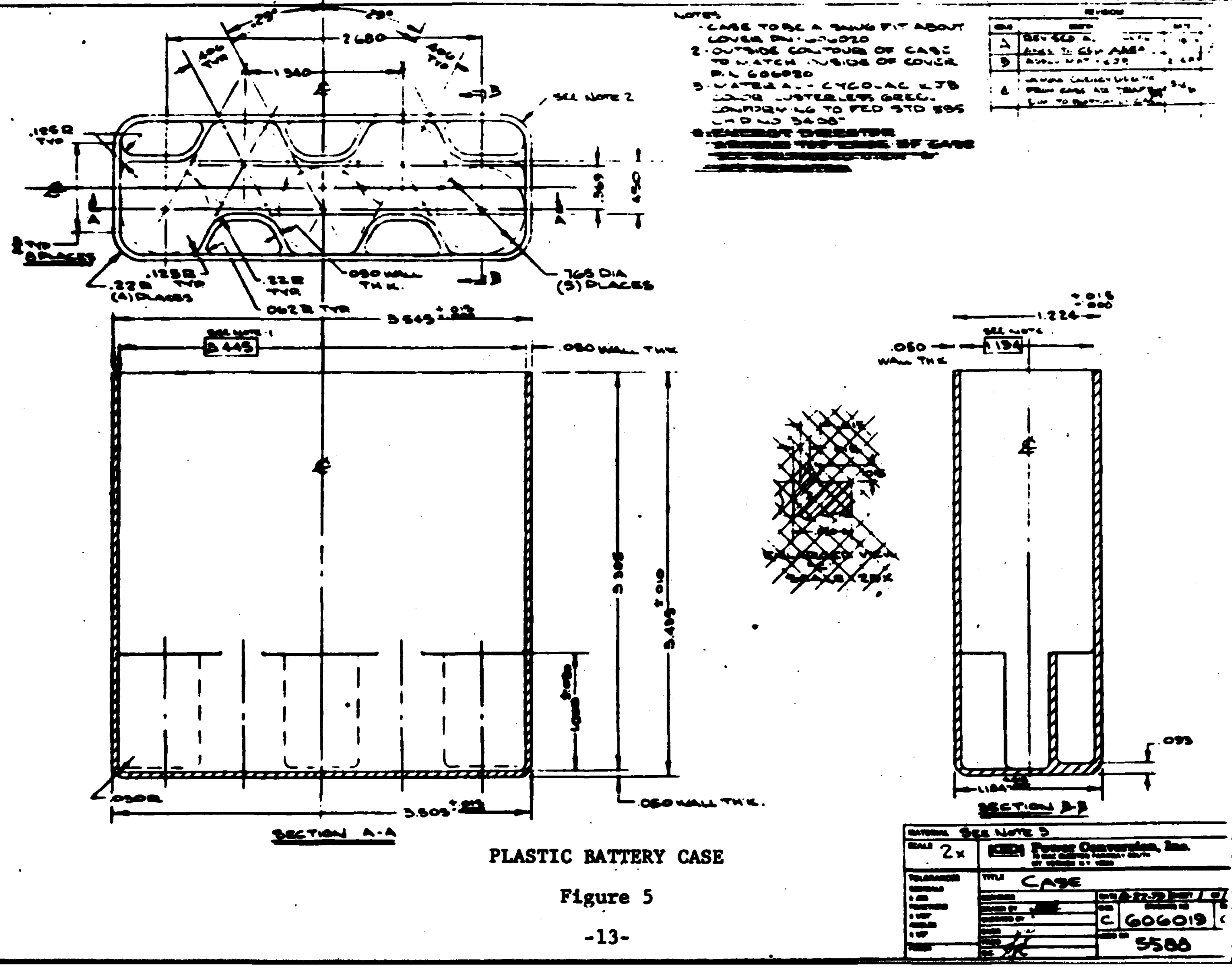
The electrical connectros utilized in the battery were snap-on terminals per ML-B-18D, each having a spacing from the centerline of the battery of 0.281 ± .0015 inches. The female snap connector was provided, as specified, with a peripheral cylindrical plastic shield which minimizes accidental short circuiting of the battery.

5.4 Insulators

Mylar insulative cell jackets .002 inches thick were installed over cell casings prior to fabrication of the cell stack assembly. As indicated in Figure 5, the molded battery case was provided with cell locating partitions which also serve to act as insulating barriers for the cell stack assembly.

5.5 Battery Venting

The battery cover is sealed to the case assembly using an ultrasonic weld technique. Each corner of the battery is left unsealed to allow the gradual release of overpressurized electrolyte in the event of venting of one or more cells.



PLASTIC BATTERY CASE

Figure 5

PLASTIC COVER

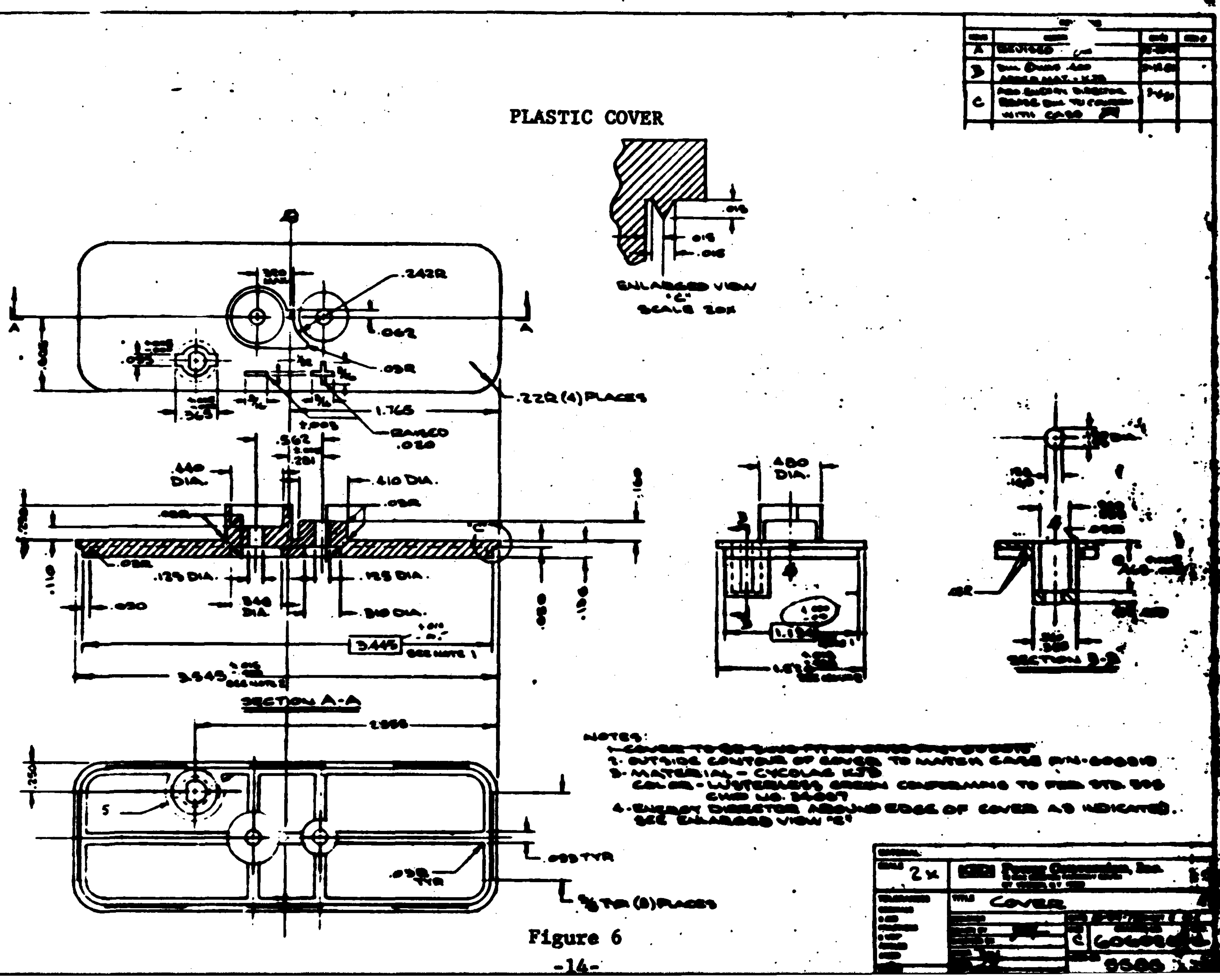


Figure 6

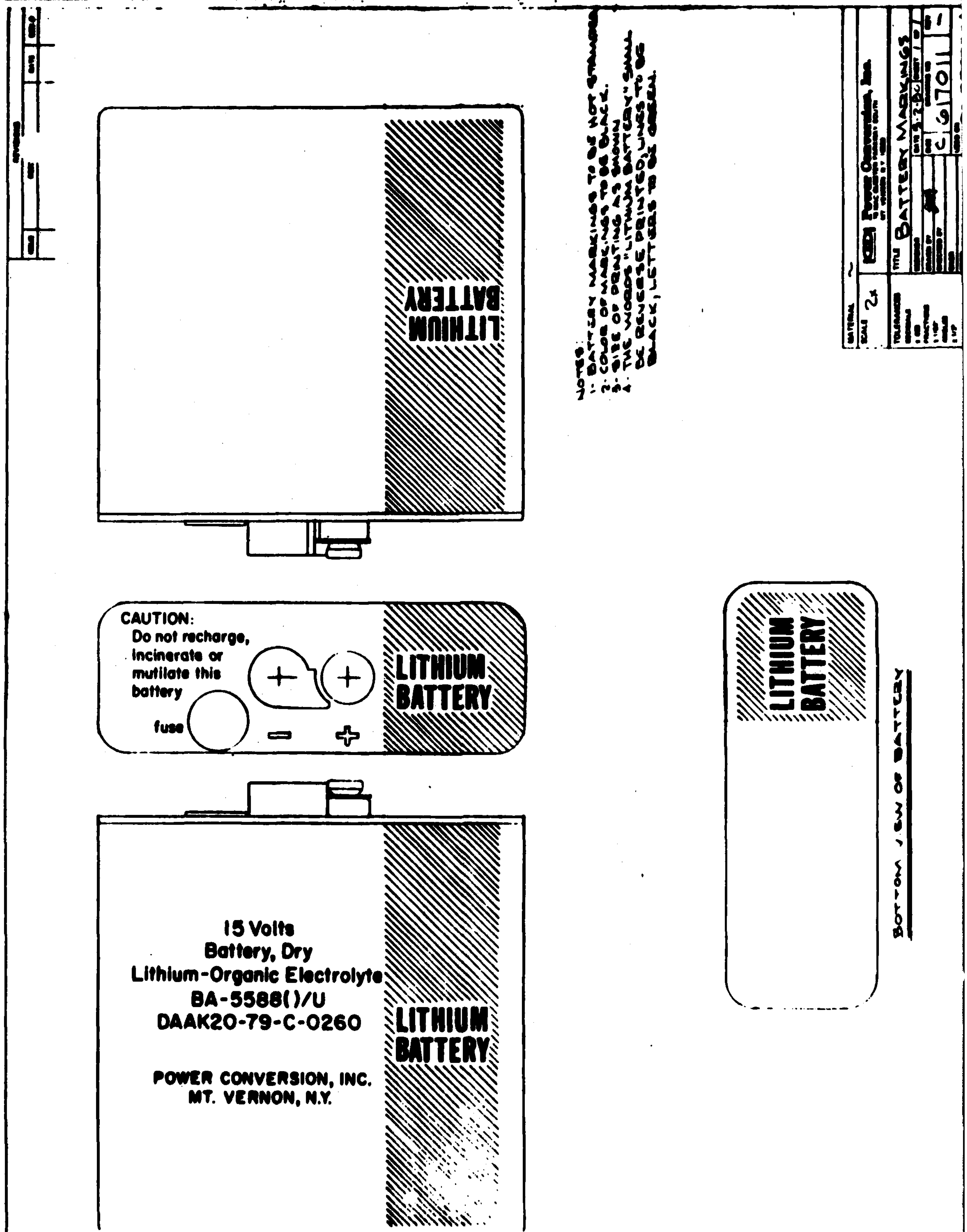
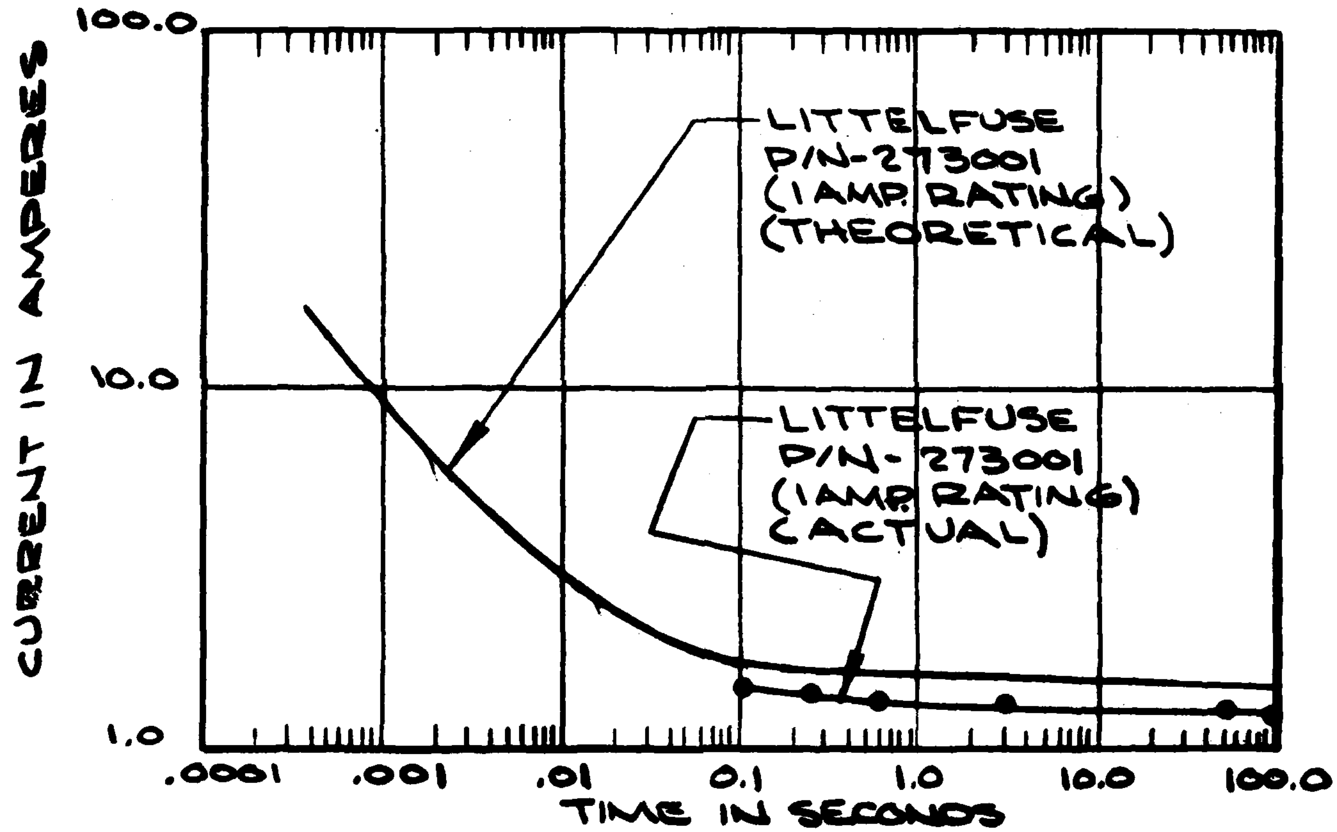

LITHIUM BATTERY
CAUTION:
Do not recharge, incinerate or mutilate this battery
fuse
LITHIUM BATTERY
15 Volts
Battery, Dry
Lithium-Organic Electrolyte
BA-5588()/U
DAAK20-79-C-0260
LITHIUM BATTERY
POWER CONVERSION, INC.
MT. VERNON, N.Y.
LITHIUM BATTERY
BOTTOM VIEW OF BATTERY
BATTERY MARKINGS
Power Conversion, Inc.

Figure 7



FUSE TIME-CURRENT CHARACTERISTICS

FIG. 8

5.6 Battery Weight

The following summarizes the projected weight contributions of the individual battery components:

Description	Weight (grams)
Cell (5 each)	225.0
Battery Case	38.5
Battery Cover	7.6
Fuse and Fuse Base	0.8
Terminals, Snap-On (including rivets)	1.7
Tabs/Hot Melt Adhesive	5.0
Misc. Wire and Insulators	3.2
Total Battery Weight	281.8 gms or 0.62 lbs.

6. PRELIMINARY DESIGN CELL FABRICATION PHASE

6.1 Cell Design I

A prototype (baseline) cell design was initially evaluated during preliminary design tests conducted at PCI to determine its feasibility for use in the BA-5588 ( )/U battery. The cells, constructed in the same manner as previously discussed in paragraph 4.3, had the following characteristics:

Anode

Active Length (inches)	6.375
Width (inches)	2.5
Thickness (inches)	0.009
Weight (gms)	1.16
Theoretical Capacity (ampere-hours)	4.31

Cathode

Active Length (inches)	6.875
Width (inches)	2.25
Thickness (inches)	0.030
Porosity (percent)	85

Separator

Type	Celgard	2400
Length (inches)		18
Width (inches)		2.75
Thickness (inches)		0.001
Porosity (percent)		45

Electrolyte

Weight (grams)	14.8
Volume (cc)	11.8

6.2 Base Line Tests

Cells were tested at +70^{0}F, +160^{0}F and -40^{0}F after thermal stabilization for sixteen (16) hours. Each cell was pulse discharged through eight ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to zero voltage. The results were as follows:

Cell S/N	Discharge Temp (^{0}F)	OCV (Volts)	Service Hours @ 2.4 Volts	Service Hours @ 0 Volts
1	+70	2.97	38.8	41.6
2	+70	2.98	36.3	42.9
3	+70	2.98	37.6	40.8
4	+70	2.99	37.0	41.6
5	+70	2.98	35.1	40.7
6	+160	2.96	36.0	39.8
7	+160	2.96	33.9	42.0
8	+160	2.97	35.8	41.5
9	+160	2.96	35.8	40.0
10	+160	2.97	35.0	39.8

Cell S/N	Discharge Temp (^{0}F)	OCV (Volts)	Start-up Voltage @ 100 ms	Service Hours @ 2.4 Volts	Service Hours @ 0 Volts
11	-40	3.02	2.00	14.7	32.8
12	-40	3.02	2.07	16.2	35.1
13	-40	3.02	2.04	15.3	34.0
14	-40	3.00	1.99	14.5	32.5
15	-40	3.01	2.10	15.5	36.0

These base-line results, while indicating that the capacity requirements could be achieved at all specified discharge temperatures, demonstrated this cells inability to meet the minimum 2.4 volt 0.1 second start-up voltage requirement. As shown in Table 1 "Cell Pulse Voltage" discharge tests indicated that an average of seven (7) cycles were required to attain a minimum operating voltage of 2.4 volts at -40^{0}F.

In order to determine the effect of electrode surface area on cell pulse voltage, a PCI model 550-HR-S high rate "D" cell, with an effective electrode surface area of 390 cm^2 was subsequently tested at -40^{O}F under the identical BA-5588 cell discharge cycle.

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
11	1	2.00	2.16	2.47
12	1	2.07	2.21	2.50
13	1	2.04	2.19	2.49
11	2	2.22	2.25	2.52
12	2	2.25	2.28	2.52
13	2	2.16	2.24	2.50
11	3	2.27	2.28	2.53
12	3	2.29	2.30	2.55
13	3	2.26	2.28	2.53
11	4	2.30	2.30	2.56
12	4	2.31	2.33	2.57
13	4	2.29	2.30	2.56
11	5	2.31	2.31	2.56
12	5	2.34	2.34	2.58
13	5	2.31	2.33	2.57
11	6	2.35	2.36	2.57
12	6	2.38	2.39	2.59
13	6	2,34	2.36	2.58
11	7	2.39	2.40	2.58
12	7	2.41	2.41	2.60
13	7	2.38	2.40	2.58
11	20	2.44	2.45	2.64
12	20	2.46	2.46	2.65
13	20	2.44	2.44	2.65
11	40	2.45	2.45	2.64
12	40	2.47	2.47	2.66
13	40	2.46	2.46	2.65

Cell Pulse Voltage at -40°F

Table 1

The results, which have been tabulated below, showed that the required start-up voltage specification could not even be routinely obtained using the PCI 550-HR-S cell; a design with nearly twice the effective surface area of the BA-5588 cell.

Cell #	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
1	1	2.16	2.40	2.63
2	1	2.10	2.33	2.62
3	1	2.04	2.34	2.64
1	2	2.41	2.45	2.64
2	2	2.32	2.34	2.63
3	2	2.37	2.39	2.64
1	3	2.45	2.46	2.64
2	3	2.38	2.40	2.64
3	3	2.40	2.41	2.64

Based on these results, initial efforts were directed towards:

a.) determining the feasibility of utilizing a six (6) cell battery design. (This approach was later abandoned due to the upper voltage limits imposed by the equipment to be powered by the subject battery.)

b.) investigating the effect of preconditioning/shorting of the cell at -40°F, by application of a short, high current pulse, prior to battery use.

c.) determining cell start-up voltage characteristics at temperatures above -40°F to quantitatively define the thermal limitations of the present design.

6.3 <u>Cell Redesign</u> (Design II)

Specific recommendations were made by ERADCOM in an effort to resolve voltage delay problems encountered during cell discharge at -40°F. The cell was redesigned and a number of tasks were performed at the request of ERADCOM to supply additional performance information and design parameters.

The cell design was modified to increase the effective electrode surface area in an effort to improve cell start-up performance at -40^{0}F. Prototype cells with safety vents were then constructed to define preliminary electrical performance. The electrode characteristics were as follows:

<u>Anode</u>

Active Length (inch)	8.5
Width (inch)	2.5
*Thickness (inch)	.008
Weight (gms)	1.49
Theoretical capacity (amp-hrs)	5.74

<u>Cathode</u>

Active Length (inch)	8.5
Width (inch)	2.5
Thickness (inch)	.030
Porosity (%)	85

<u>Separator</u>

Type	Celgard 2400
Length (inch)	23
Width (inch)	2.75
Thickness (inch)	.001
Porosity (%)	45

<u>Electrolyte</u>

Weight (grams)	14
Volume (cc)	11.2
Theoretical Capacity (amp-hrs)	4.02

*A lithium foil thickness of .006 in. was proposed for final design, but was not available for initial prototype cells.

6.3.1 <u>Discharge -40^{0}F</u>

Cells were pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to 2.4 volts after thermal stabilization for sixteen (16) hours at -40^{0}F. The capacity results were as follows:

Cell S/N	Discharge Temp (^0F)	OCV (volts)	Start-up Voltage @ 100 ms (volts)	Service Hours @ 2.4 volts
76	-40	3.03	2.14	13.0
77	-40	3.02	2.10	12.6
78	-40	3.01	2.07	14.1
79	-40	3.04	2.10	13.5
80	-40	3.02	2.07	12.9

These results again indicated that the specification capacity requirements at -40^0F were attainable. However, the start-up voltage requirement of 2.4 volts within 0.1 seconds was not achieved, although the results were significantly improved from the previous baseline results. A summary of operational cell voltage during the above discharge is shown below for cells S/N 76 - 80:

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
76	1	2.14	2.27	2.54
77	1	2.10	2.25	2.56
78	1	2.07	2.23	2.55
79	1	2.10	2.28	2.57
80	1	2.07	2.26	2.53
76	2	2.26	2.34	2.57
77	2	2.25	2.31	2.59
78	2	2.24	2.31	2.58
79	2	2.29	2.34	2.59
80	2	2.25	2.32	2.56
76	3	2.35	2.37	2.59
77	3	2.32	2.34	2.60
78	3	2.32	2.36	2.59
79	3	2.35	2.38	2.59
80	3	2.34	2.35	2.57
76	4	2.38	2.40	2.60
77	4	2.35	2.37	2.61
78	4	2.37	2.38	2.61
79	4	2.38	2.40	2.60
80	4	2.36	2.37	2.58

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
76	5	2.40	2.42	2.62
77	5	2.39	2.41	2.63
78	5	2.40	2.40	2.62
79	5	2.41	2.43	2.63
80	5	2.39	2.40	2.60
76	6	2.44	2.45	2.64
77	6	2.41	2.43	2.65
78	6	2.43	2.45	2.64
79	6	2.44	2.46	2.66
80	6	2.42	2.44	2.62

The above results indicated that an average of five (5) cycles was required to attain a minimum operating voltage of 2.4 volts.

6.3.2 Start-up Voltage under continuous load

An additional test was performed to determine the amount of time required to attain 2.4 volts under an 8 ohm load at -40^{0}F at which time the cell was immediately exposed to the pulsed discharge duty cycle. The results were as follows:

Cell S/N	Time to 2.4v @ 8 ohms (minutes)	Voltage @ 9 mins at 41.4 ohms	Voltage @ 100 ms at 8 ohms
81	4.0	2.61	2.41
82	3.5	2.64	2.42
84	4.3	2.63	2.39
85	3.8	2.63	2.41

These results indicated an average time of 3.9 minutes to attain a minimum operating voltage of 2.4 volts. This minimum voltage was maintained after subsequent pulsed discharge cycles.

6.3.3 Voltage Start-up Tests at -20^{0}F and 0^{0}F

The redesigned cell (Design II) was tested at -20^{0}F and 0^{0}F after thermal stabilization for sixteen (16) hours to determine the temperature at which the present voltage start-up specification could be attained. Each cell was pulse discharged in accordance with the specification: a summary of operational cell voltage during this test is shown below:

Test Temperature: -20°F

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
86	1	2.22	2.32	2.62
87	1	2.24	2.35	2.64
88	1	2.19	2.31	2.61
89	1	2.24	2.34	2.63
86	2	2.34	2.38	2.63
87	2	2.37	2.42	2.65
88	2	2.32	2.37	2.63
89	2	2.34	2.40	2.64
90	2	2.37	2.42	2.65
86	3	2.39	2.43	2.65
87	3	2.42	2.45	2.66
88	3	2.37	2.40	2.64
89	3	2.41	2.43	2.66
90	3	2.43	2.46	2.67

Test Temperature: 0°F

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
91	1	2.40	2.51	2.66
92	1	2.43	2.50	2.65
93	1	2.41	2.50	2.67
94	1	2.41	2.48	2.67
95	1	2.42	2.52	2.67

The above results indicate that an average of 2.4 cycles was required at -20°F to attain a minimum operating voltage of 2.4 volts. The present start-up specification was attained at 0°F with the "Design II" type cell.

The pulse start-up voltage delay was subsequently verified by continuously applying an 8 ohm load at temperatures of -40°F, -20°F and 0°F. The results below correlate quite closely to the data obtained under the pulsed duty cycle load.

Cell S/N	Test Temperature (°F)	Time @ 2.4 volts (minutes)
96	-40	3.9
97	-40	3.5

Cell S/N	Test Temperature (^{0}F)	Time @ 2.4 volts (minutes)
98	-20	1.75
99	-20	2.0
100	0	100 ms
101	0	100 ms

6.3.4 Cathode Construction Investigation

As part of this program, cathodes were fabricated using carbon, which was evenly distributed, on both sides of the conductive grid to determine its effect on cell start-up voltage at -40^{o}F (PCI's standard electrodes have 95% of the active carbon/binder material on one side of the expanded conductive substrate). Four (4) prototype cells were fabricated and pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes after thermal stabilization for sixteen (16) hours at -40^{o}F. The results, as summarized below, show no significant improvement in start-up performance as compared to data previously obtained.

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
102	1	2.16	2.30	2.57
103	1	2.16	2.28	2.57
104	1	2.10	2.24	2.53
105	1	2.09	2.25	2.54
102	2	2.30	2.36	2.59
103	2	2.29	2.33	2.59
104	2	2.25	2.30	2.58
105	2	2.27	2.33	2.58
102	3	2.36	2.38	2.60
103	3	2.34	2.36	2.61
104	3	2.32	2.35	2.59
105	3	2.34	2.37	2.59
102	4	2.39	2.41	2.61
103	4	2.37	2.40	2.62
104	4	2.36	2.38	2.61
105	4	2.38	2.40	2.60
102	5	2.41	2.42	2.63
103	5	2.41	2.42	2.63
104	5	2.40	2.41	2.63
105	5	2.40	2.43	2.60

6.4 CELL REDESIGN (Design III)

The internal cell design was again modified in an effort to optimize cell start-up performance at -40°F Electrode lengths were slightly increased resulting in an effective surface area of 290 cm^2. An alternative cathode formulation and rolling process was used in an effort to improve carbon adhesion to the conductive grid and reduce overall cell impedance. These cathodes were fabricated utilizing an alcohol/aqueous solvent composite and a horizontal rolling mill process to obtain the desired cathode thickness (.026 inch) and carbon weight of .125 grams (Type IIIA) per square inch. Cathode material was deposited on one side of the conductive grid for this experiment. Prototype cells with safety vents were constructed to define electrical performance. The electrode characteristics were as follows:

Anode

Active Length (inch)	9.0
Width (inch)	2.5
*Thickness (inch)	.008
Weight (gms)	1.58
Theoretical capacity (amp-hrs)	6.08

Cathode

Active Length (inch)	9.0
Width (inch)	2.5
Thickness (inch)	.026
Porosity (%)	85

Separator

Type	Celgard 2400
Length (inch)	24
Width (inch)	2.75
Thickness (inch)	.001
Porosity (%)	45

Electrolyte

Weight (grams)	14
Volume (cc)	11.2
Theoretical Capacity (amp-hrs)	4.02

*A lithium thickness of .006 in was specified for final design (pp 7-8) but was not available for these cells.

6.4.1 Start-up Tests $-40^{O}F$; Cathode 0.125 gms C/in^2 (III A)

These prototype cells were subsequently tested at $-40^{O}F$ after thermal stabilization for sixteen (16) hours. Each cell was pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to 2.4 volts. The results, as summarized below, show a slight improvement in start-up performance as compared to data previously obtained on Type II cells.

Design III A Cells

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
106	1	2.19	2.32	2.57
107	1	2.17	2.28	2.57
108	1	2.16	2.28	2.56
109	1	2.21	2.33	2.58
110	1	2.19	2.30	2.57
106	2	2.32	2.35	2.60
107	2	2.30	2.33	2.59
108	2	2.30	2.32	2.58
109	2	2.34	2.35	2.60
110	2	2.31	2.34	2.59
106	3	2.36	2.39	2.62
107	3	2.34	2.37	2.61
108	3	2.33	2.36	2.60
109	3	2.35	2.38	2.61
110	3	2.36	2.38	2.60
106	4	2.40	2.42	2.63
107	4	2.39	2.41	2.62
108	4	2.38	2.40	2.61
109	4	2.39	2.41	2.62
110	4	2.40	2.42	2.62

6.4.2 Cell Start-up Voltage After Partial Predischarging

Additional Type IIIA cells were predischarged (preconditioned) by applying a 1.5 ohm resistance for ten (10) minutes (approximately 0.3 AH) to reduce the internal impedance of the cell. Five cells were subsequently stored at $+160^{O}F$ for two (2) days and tested at $-40^{O}F$ after thermal stabilization for sixteen (16) hours. Each cell was pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to 2.4 volts. The results, as summarized below,

show a significant improvement in start-up performance. The average time to attain a minimum of 2.4 volts was 50 seconds.

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec. 8 ohms	Voltage @ 41.4 ohms
116	1	2.23	2.42	2.63
117	1	2.25	2.40	2.62
118	1	2.29	2.44	2.64
119	1	2.21	2.41	2.62
120	1	2.21	2.41	2.62

6.4.3 Start-Up Voltage Tests; Cathode 0.160 gms C/in^2 (III B)

Additional "Design III" cells were fabricated using cathodes fabricated with an alcohol/aqueous solvent composite and a horizontal rolling mill process to obtain the desired cathode thickness (.026 inch) and an increased weight to .160 grams (Type IIIB) of carbon per square inch. Cathode material was deposited on both sides of the conductive grid to increase the effective electrode surface area.

These prototype cells were subsequently tested as before. The results, as summarized below, show no improvement in start-up performance as compared to data obtained with Type III A cathodes having .125 gms carbon per square inch.

Type IIIB Cells

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec. 8 ohms	Voltage @ 41.4 ohms
111	1	2.16	2.30	2.57
112	1	2.20	2.32	2.57
113	1	2.16	2.26	2.55
114	1	2.19	2.28	2.56
115	1	2.22	2.33	2.58
111	2	2.30	2.34	2.59
112	2	2.33	2.35	2.58
113	2	2.27	2.30	2.56
114	2	2.30	2.33	2.57
115	2	2.34	2.36	2.59
111	3	2.34	2.37	2.60
112	3	2.35	2.38	2.60
113	3	2.31	2.35	2.58
114	3	2.34	2.37	2.59
115	3	2.37	2.40	2.60

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
111	4	2.38	2.40	2.61
112	4	2.38	2.40	2.61
113	4	2.36	2.39	2.59
114	4	2.37	2.40	2.60
115	4	2.41	2.43	2.62

6.4.4 Start-Up Voltage Tests Multiple Cathode Grids (Type IIIC)

An experiment was subsequently conducted to determine the effect of multiple conductive grids within the cathode. Prototype cells using the standard cathode formulation and two aluminum current collection grids were fabricated using the electrode design as summarized in paragraph 6.4.

These cells were subsequently tested at $-40^{0}F$ after thermal stabilization for sixteen (16) hours. Each cell was pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to 2.4 volts. The results, as summarized below, show somewhat poorer start-up performance as compared to data reported in paragraphs 6.4.1. Such results are attributed to the reduced effective surface area of the cathode due to the masking effect of the two conductive grids which were utilized.

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec. 8 ohms	Voltage @ 41.4 ohms
121	1	1.80	2.06	2.47
122	1	1.89	2.08	2.49
123	1	1.82	1.94	2.48
124	1	1.93	1.99	2.50
125	1	1.96	2.09	2.50
121	2	2.14	2.15	2.52
122	2	2.18	2.20	2.59
123	2	2.16	2.17	2.53
124	2	2.19	2.23	2.58
125	2	2.20	2.24	2.58
121	3	2.20	2.20	2.55
122	3	2.25	2.26	2.57
123	3	2.23	2.23	2.55
124	3	2.26	2.28	2.58
125	3	2.27	2.30	2.59

Voltage Start-Up Tests (continued)

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec. 8 ohms	Voltage @ 41.4 ohms
121	4	2.24	2.24	2.57
122	4	2.27	2.27	2.58
123	4	2.30	2.30	2.57
124	4	2.31	2.32	2.59
125	4	2.31	2.34	2.60
121	5	2.28	2.29	2.58
122	5	2.33	2.34	2.59
123	5	2.31	2.31	2.58
124	5	2.33	2.35	2.59
125	5	2.35	2.38	2.61
121	6	2.31	2.30	2.59
122	6	2.35	2.35	2.60
123	6	2.31	2.30	2.59
124	6	2.37	2.39	2.60
125	6	2.39	2.40	2.61

Additional cells of the above design were preconditioned by applying a 1.5 ohm resistance for ten (10) minutes (approximately 0.3 AH) to reduce the internal impedance of the cell. Five cells were subsequently stored at +160^{0}F for two (2) days and tested at -40^{0}F after thermal stabilization for sixteen (16) hours. Each cell was pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to 2.4 volts. The results, as summarized below, show a significant improvement in start-up performance which verifies the results shown in paragraph 6.4.2 above.

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec. 8 ohms	Voltage @ 41.4 ohms
126	1	2.13	2.33	2.58
127	1	2.21	2.32	2.58
128	1	2.27	2.34	2.58
129	1	2.26	2.35	2.59
130	1	2.20	2.35	2.59

Voltage Start-Up Tests (continued)

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec. 8 ohms	Voltage @ 41.4 ohms
126	2	2.39	2.40	2.60
127	2	2.38	2.41	2.61
128	2	2.39	2.40	2.60
129	2	2.39	2.42	2.61
130	2	2.40	2.42	2.61
126	3	2.42	2.43	2.62
127	3	2.41	2.42	2.62
128	3	2.42	2.43	2.62
126	4	2.43	2.44	2.63
127	4	2.42	2.44	2.62
128	4	2.43	2.44	2.63
126	5	2.44	2.45	2.64
127	5	2.43	2.44	2.64
128	5	2.44	2.45	2.63
126	6	2.45	2.46	2.64
127	6	2.44	2.45	2.63
128	6	2.45	2.46	2.64
126	7	2.45	2.46	2.65
127	7	2.45	2.46	2.64
128	7	2.46	2.46	2.65

The average time to attain a minimum of 2.4 volts was 1.4 cycles.

6.4.5 Preconditioning Study Type IIIA Cells

A study was performed on Type IIIA cells (see paragraph 6.4 and 6.4.1) to determine the effects of various pre-conditioning regimes on cell start-up voltage at -40°F both before and after storage. Five (5) cells each were pre-conditioned at 1.54 ohms for various time periods including 1,2, 5 and 10 minutes. The load voltages recorded under this pre-conditioning profiles were as follows:

Cell S/N	OCV	Start-up Voltage (5 seconds)	Final Voltage	Time Duration (mins)
129	2.97	2.32	2.68	10
130	2.96	2.40	2.69	10
131	2.97	2.35	2.70	10
132	2.96	2.38	2.70	10
133	2.96	2.41	2.69	10
134	2.96	2.34	2.66	5
135	2.96	2.42	2.67	5
136	2.96	2.34	2.66	5
137	2.97	2.36	2.66	5
138	2.95	2.41	2.65	5
139	2.96	2.32	2.65	2
140	2.95	2.33	2.62	2
141	2.96	2.30	2.62	2
142	2.96	2.28	2.64	2
143	2.96	2.48	2.63	2
144	2.95	2.36	2.58	1
145	2.96	2.31	2.55	1
146	2.95	2.33	2.59	1
* 147	2.90	2.59	2.66	1
148	2.97	2.29	2.60	1

* Inadvertantly shorted during test.

Representative samples of the above cells were pre-conditioned in an identical manner, stored for two (2) days at +160^{o}F and tested at -40^{o}F after thermal stabilization for sixteen (16) hours. Each cell was pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to 2.4 volts. The results, as summarized below, show equivalent start-up performance for these cells independent of the pre-conditioning discharge profile.

Cell S/N	Pre-condition Time Profile @ 1.54 ohms
149,150	10 minutes
151,152	5 minutes
153,154	2 minutes
155,156	1 minute

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
149	1	2.21	2.32	2.58
150	1	2.27	2.35	2.58
151	1	2.24	2.34	2.59
152	1	2.24	2.34	2.58
153	1	2.27	2.35	2.57
154	1	2.28	2.35	2.59
155	1	2.25	2.32	2.57
156	1	2.31	2.37	2.60
149	2	2.38	2.41	2.61
150	2	2.39	2.40	2.61
151	2	2.40	2.42	2.62
152	2	2.39	2.42	2.62
153	2	2.39	2.41	2.59
154	2	2.41	2.42	2.61
155	2	2.38	2.39	2.60
156	2	2.43	2.44	2.63
149	3	2.41	2.42	-
150	3	2.42	2.43	-
151	3	2.44	2.45	-
152	3	2.43	2.45	-
153	3	2.41	2.44	-
154	3	2.44	2.45	-
155	3	2.41	2.42	-
156	3	2.45	2.47	-

In order to determine the effects of long term, high temperature storage on preconditioning, the cells listed below were stored for thirty (30) days at +160°F after preconditioning.

Cell S/N	Pre-condition Time Profile @ 1.54 ohms
134-138	5 minutes
139-143	2 minutes
144-148	1 minute
157-161	No preconditioning

Upon completion of the storage period the above cells were pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously for a minimum of five (5) cycles after thermal stabilization at -40°F for sixteen (16) hours. Typical results are summarized below:

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
134	1	.50	.69	2.38
135	1	.94	1.70	2.48
136	1	.61	.87	2.36
141	1	1.21	1.45	2.43
142	1	1.43	1.83	2.48
143	1	1.56	1.94	2.50
144	1	1.23	1.80	2.47
145	1	1.42	1.79	2.48
146	1	1.83	1.95	2.48
157	1	1.85	2.07	2.54
158	1	1.78	2.04	2.52
159	1	1.64	1.93	2.47
134	2	2.06	2.19	2.49
135	2	2.20	2.30	2.54
136	2	2.02	2.19	2.47
141	2	2.08	2.09	2.49
142	2	2.22	2.23	2.54
143	2	2.23	2.26	2.56
144	2	2.16	2.18	2.51
145	2	2.16	2.18	2.52
146	2	2.15	2.14	2.50
157	2	2.21	2.22	2.57
158	2	2.22	2.23	2.56
159	2	2.20	2.27	2.53
134	3	2.21	2.14	2.53
135	3	2.29	2.27	2.57
136	3	2.15	2.13	2.51
141	3	2.18	2.15	2.52
142	3	2.30	2.30	2.57
143	3	2.31	2.32	2.58
144	3	2.24	2.23	2.56
145	3	2.24	2.23	2.56
146	3	2.20	2.16	2.52
157	3	2.27	2.27	2.59
158	3	2.28	2.29	2.59
159	3	2.28	2.28	2.56

Cell S/N	Pulse #	Voltage @ 100 ms 8 ohms	Voltage @ 60 sec 8 ohms	Voltage @ 41.4 ohms
134	4	2.27	2.18	2.54
135	4	2.34	2.32	2.58
136	4	2.22	2.18	2.53
141	4	2.22	2.19	2.54
142	4	2.34	2.34	2.59
143	4	2.35	2.36	2.60
144	4	2.28	2.27	2.58
145	4	2.28	2.28	2.58
146	4	2.23	2.18	2.54
157	4	2.31	2.31	2.60
158	4	2.32	2.33	2.60
159	4	2.31	2.32	2.59
134	5	2.30	2.22	2.56
135	5	2.36	2.34	2.59
136	5	2.25	2.20	2.45
141	5	2.27	2.22	2.59
142	5	2.38	2.37	2.59
143	5	2.38	2.38	2.61
144	5	2.32	2.30	2.59
145	5	2.33	2.31	2.59
146	5	2.28	2.20	2.55
157	5	2.31	2.36	2.61
158	5	2.35	2.35	2.61
159	5	2.34	2.35	2.60

The results indicated that the preconditioning profiles evaluated did not provide any beneficial effects on start-up voltage after thirty days storage at +160°F.

7. CELL FABRICATION AND TEST PHASE

The specified test program was performed to provide the following:

- Demonstration of cell hermeticity and integrity after prolonged exposure to elevated temperatures and environmental tests.

- Evaluation of cell performance under the specified resistive load discharge profile at various temperatures after thirty (30) days storage at +160°F.

- Demonstration of cell safety under specified abusive test environments.

One hundred (100) cells were fabricated during this phase of the development program. Fifty (50) cells were forwarded to ERADCOM for inspection and evaluation in accordance with CLIN 0001. The remaining fifty (50) cells were subjected to the following tests:

7.1 Environmental Tests

Prior to conducting the environmental tests, all cells were weighed to the nearest milligram. The cells were then subjected to the following environments in the sequence given:

- Temperature Shock - In accordance with MIL-STD-810C, Method 503.1, for five cycles.

- Shock - In accordance with MIL-STD-810C, Method 516.2, Procedure I, Curve 516.2-2 for ground equipment.

- Vibration - In accordance with MIL-STD-810C, Method 514.2, Equipment Category (h), Procedures X & XI, Fig. 514.2-7, Table 514.2-VII.

- Altitude - In accordance with MIL-STD-810C, Method 500.1, Procedure I (omit operation in Step 4).

At the conclusion of the above tests, each cell was again weighed to the nearest milligram. In addition, the open circuit voltage and closed circuit voltage (1.54 ohm resistive load for 30 seconds) of each cell was measured to verify electrical integrity after environmental exposure (for information only).

HIGH TEMPERATURE STORAGE

All cells were subsequently stored at +160°F for thirty (30) days. The cells were removed, cooled for one hour in a dry atmosphere and immediately weighed to the nearest milligram.

7.2 Discharge Tests

Room Temperature Tests - After undergoing the environmental and high temperature storage tests, ten (10) cells were selected at random and discharged under the specified load profile at 75°F ± 7°F. The cells were stabilized at that temperature for at least one hour prior to discharge. The cell discharge was continuously monitored for temperature and voltage to zero volts. The cells service life requirement is thirty (30) hours minimum.

Elevated Temperature Tests - Ten cells were randomly selected from the remaining cells, stored at +130°F for a minimum of eight (8) hours and discharged under the specified load profile at 130°F + 30°F. The cell discharge was monitored for temperature and voltage to zero volts. The cells service life requirement is thirty (30) hours minimum.

High Temperature Tests - Ten cells were randomly selected from the remaining cells, stored at 160°F ± 3°F for a minimum of eight (8) hours and discharged under the specified load profile at 160°F ± 3°F. The cell discharge was monitored for temperature and voltage to zero volts. The cells service life requirement is thirty (30) hours minimum.

Low Temperature - Ten cells were randomly selected from the remaining cells, stored at -40°F for a minimum of eight (8) hours and discharged under the specified load profile at -40°F. The cell discharge was continuously monitored to zero volts. The cells service life requirement is ten (10) hours minimum.

Forced Discharge - The remaining ten (10) cells were force discharged by placing each cell in series with a power supply and driving it at 0.5 amperes without interruption for sixteen (16) hours or until venting occurs. Time to venting, cell temperature, voltage and current were recorded. The tests were conducted under room temperature conditions.

7.3 TEST RESULTS AND OBSERVATIONS

7.3.1 Environmental Tests

The results and observations of the specified environmental tests (temperature shock, shock, vibration) are described in Appendix A, Stanford Technology Corporation, Test Report ST-2220 dated 5 February 1980. All cells successfully passed the above environmental tests with the exception of S/N 69 which exhibited evidence of electrolyte leakage adjacent to the fill port closure immediately following exposure to Temperature Shock. This leakage was subsequently verified by a resulting loss of cell weight.

Subsequent failure analysis showed that the observed electrolyte leakage was due to a cracked weld within the fill port closure; a condition most likely due to stresses developed during the thermal shock environment. The following corrective action was implemented to screen this condition on subsequent cells:

- Completed cells will be subjected to three (3) days storage at +160°F after electrolyte fill. A visual examination for electrolyte leakage will be conducted after each day of storage.

- Inspection surveillance of the fill port closure operation will be increased to verify the quality of the welded joint and the use of proper weld parameters.

All cells (with the exception of S/N 69) were subjected to the Altitude Test as specified. The results are summarized in Appendix B. No electrolyte leakage or other adverse effects were observed during or after environmental exposure.

7.3.2 Electrical Check

The open circuit voltage (OCV) and closed circuit voltage (CCV) at 1.54 ohms, 30 seconds, was measured to determine the electrical condition of the fifty (50) cells after environmental exposure. The results are summarized in Table 2. No evidence of cell failure was observed.

7.3.3 Cell Hermeticity

Cell weight values to the nearest milligram taken during various phases are presented in Table 3. The results show that the maximum weight loss did not exceed 0.00 percent of the sulfur dioxide content of the cell after environmental exposure and storage at +160°F for thirty (30) days (with the exception of S/N 69 as previously discussed). Observed cell weight variations are within the sensitivity of the analytical balance. All cells showed a slight weight gain; a condition attributed to moisture absorption of the insulative mylar jacket and epoxy encapsulant within the top shell assembly. No visual evidence of electrolyte leakage was observed on any of the cells.

7.3.4 Capacity Tests

Thirty nine (39) cells were randomly selected from the cells that had undergone environmental exposure and +160°F storage for thirty (30) days. Ten (10) cells were discharged after stabilization for eight (8) hours at +160°F, +130°F and -40°F. Nine (9) cells were discharged at +70°F. Each cell was pulse discharged through 8 ohms for one (1) minute followed by 41.4 ohms for nine (9) minutes repeated continuously to zero volts. Cell output voltage and temperature was continuously monitored as specified. The capacity discharge results are shown in Table 4. No cell venting was observed during discharge to zero volts. The results show that the cells successfully complied with all specified minimum service life requirements.

The minimum start-up voltage requirement of 2.4 volts within 0.1 seconds was not achieved during discharge at -40°F. The results indicate that an average of 6.6 cycles was required to attain a minimum operating voltage of 2.4 volts after cell storage at +160°F for thirty (30) days. A summary of operational cell voltage during the first eight (8) cycles of the -40°F discharge is shown in Table 5.

7.3.5 Forced Discharge

The remaining ten (10) cells were force discharged at 0.5 amperes without interruption for sixteen (16) hours or until venting occurred. Time to venting, cell temperatures, output voltage and current was continuously monitored as specified. The results, as summarized in Table 6, showed that the cells complied with all safety requirements of the Technical Guidelines. No explosive conditions or other adverse effects were observed.

7.4 CONCLUSIONS:

Electrical Performance

Cell capacity exceeded all minimum service requirements under the discharge load temperatures after storage at +160°F for thirty (30) days. An average of 6.6 load cycles (transmit/receive) was required to attain a minimum cell operational voltage of 2.4 volts under the 8 ohm resistive load (transmit mode) at -40°F. No electrolyte leakage or other adverse conditions were observed after environmental exposure and storage for thirty (30) days at +160°F.

Safety Performance

All cells performed satisfactorily under the specified abusive test environments in accordance with the requirements of the Technical Guidelines.

Power Conversion, Inc.
70 MAC QUESTEN PARKWAY SOUTH
MT. VERNON, N.Y. 10550

Date 2-28-80
Sheet 1 of 1

TEST DATA SHEET

Battery P/N BA-5588/U Customer ERADCOM P/N B500083
Test ELECTRICAL CHECK Test Procedure OCV, CCV (POST ENVIRONMENTAL)
Acceptance Criteria INFORMATION ONLY
Purchase Order No. DAAK20-79-C-0260

CELL S/N	OCV (VOLTS)	CCV @1.54Ω 30 SEC. (VOLTS)			CELL S/N	OCV (VOLTS)	CCV @1.54Ω 30 SEC. (VOLTS)		
1	2.97	2.34			47	2.97	2.32		
3	2.97	2.33			49	2.96	2.36		
5	2.97	2.34			50	2.97	2.30		
10	2.97	2.33			51	2.96	2.36		
11	2.97	2.33			53	2.96	2.33		
12	2.96	2.35			54	2.97	2.28		
17	2.96	2.36			56	2.96	2.35		
19	2.97	2.39			58	2.97	2.37		
20	2.97	2.35			59	2.97	2.32		
[illegible]	2.97	2.40			62	2.96	2.36		
23	2.96	2.39			65	2.96	2.40		
24	2.96	2.36			66	2.96	2.34		
[illegible]	2.97	2.32			69	2.95	2.30		
29	2.97	2.35			70	2.97	2.34		
30	2.97	2.37			72	2.97	2.35		
31	2.97	2.41			73	2.97	2.31		
32	2.97	2.32			74	2.96	2.37		
33	2.97	2.33			75	2.96	2.40		
37	2.97	2.39			76	2.97	2.32		
38	2.96	2.36			78	2.97	2.31		
39	2.96	2.35			87	2.97	2.37		
40	2.97	2.33			88	2.97	2.35		
42	2.97	2.35			89	2.96	2.38		
[illegible]	2.96	2.34			92	2.97	2.40		
[illegible]	2.97	2.30			96	2.97	2.34		

TABLE 2

Power Conversion, Inc.
70 MAC QUESTEN PARKWAY SOUTH
MT. VERNON, N.Y. 10550

Date 4/25/80
Sheet 1 of 2

TEST DATA SHEET

Battery P/N BA-5588 Customer ERADCOM P/N 600023
Test SO_2 Weight Loss Test Procedure Tech. Guidelines, para. 3.3.2
Acceptance Criteria 0.00 % SO_2
Purchase Order No. DAAK20-79-C-0260

CELL S/N	INITIAL WEIGHT (GMS)	WEIGHT AFTER ENV-TEST (GMS)	WEIGHT @ 30 DAYS +160°F (GMS)	WEIGHT LOSS (-) OR GAIN (+) (GMS)				
1	44.4664	44.4669	44.4702	+.0038				
3	44.4841	44.4839	44.4845	+.0004				
5	45.0647	45.0656	45.0669	+.0038				
10	44.6697	44.6695	44.6737	+.0040				
11	44.3634	44.3630	44.3659	+.0025				
12	44.5307	44.5307	44.5329	+.0022				
17	44.9299	44.9296	44.9332	+.0033				
19	44.6037	44.6039	44.6042	+.0005				
20	44.5529	44.5525	44.5570	+.0041				
	44.6718	44.6727	44.6752	+.0034				
23	44.9448	44.9447	44.9475	+.0027				
24	44.1936	44.1936	44.1958	+.0022				
28	44.4664	44.4666	44.4676	+.0012				
29	45.3779	45.3789	45.3784	+.0005				
30	44.8548	44.8556	44.8567	+.0019				
31	44.4337	44.4344	44.4374	+.0037				
32	44.9304	44.9309	44.9320	+.0016				
33	44.0744	44.0747	44.0763	+.0019				
37	45.3848	45.3859	45.3881	+.0033				
38	44.2482	44.2487	44.2524	+.0042				
39	44.9682	44.9689	44.9709	+.0027				
40	44.9634	44.9639	44.9647	+.0013				
42	44.2019	44.2018	44.2029	+.0010				
	44.4183	44.4180	44.4219	+.0036				
45	44.3843	44.3855	44.3874	+.0034				

TABLE 3

Power Conversion, Inc.
70 MAC QUESTEN PARKWAY SOUTH
MT. VERNON, N.Y. 10550

Date 4/25/80
Sheet 2 of 3

TEST DATA SHEET

Battery P/N BA-5588 Customer ERADCOM P/N 600623
Test SO_2 Weight Loss Test Procedure Tech. Guidelines, para. 3.3.2
Acceptance Criteria 0.00 % SO_2
Purchase Order No. DAAK20-79-C-0260

CELL S/N	INITIAL WEIGHT (GMS)	WEIGHT AFTER ENV-TEST (GMS)	WEIGHT @ 30DAYS +160°F (GMS)	WEIGHT LOSS (-) OR GAIN (+) (GMS)
47	44.9148	44.9152	44.9184	+.0036
49	44.8155	44.8162	44.8185	+.0030
50	44.8286	44.8284	44.8315	+.0029
51	44.8057	44.8059	44.8072	+.0015
53	44.2690	44.2699	44.2691	+.0001
54	45.2594	45.2596	45.2602	+.0008
56	44.5572	44.5580	44.5573	+.0001
[illegible]	44.8852	44.8859	44.8890	+.0038
59	44.1694	44.1703	44.1725	+.0031
	45.2590	45.2596	45.2628	+.0038
65	45.5480	44.5477	44.5482	+.0002
66	44.6088	44.6088	44.6123	+.0035
70	45.0185	45.0192	45.0186	+.0001
72	43.9876	43.9871	43.9916	+.0020
73	44.6856	44.6855	44.6885	+.0019
74	44.0125	44.0129	44.0128	+.0003
75	44.5255	44.5256	44.5291	+.0036
76	44.5060	44.5063	44.5082	+.0022
78	44.2310	44.2321	43.2343	+.0033
87	44.7116	44.7119	44.7146	+.0030
88	44.1282	44.1289	44.1285	+.0003
89	43.8603	43.8610	43.8633	+.0030
[illegible]	44.2626	44.2635	44.2649	+.0020
	44.4107	44.4109	44.4119	+.0012
*	44.4207	43.1079	-	-1.3128

TABLE 3

* Cell leakage during environmental tests

CELL QUALIFICATION TEST PHASE

CELL TYPE: BA-5588/U
TEST: CAPACITY
STORAGE HISTORY: 30 DAYS AT +160°F
DISCHARGE PROFILE: 8 OHMS, 1 MINUTE
41.4 OHMS, 9 MINUTES

CELL S/N	OCV (VOLTS)	AVERAGE OUTPUT VOLTAGE @8Ω PULSE (VOLTS)	AVERAGE OUTPUT VOLTAGE @41.4Ω PULSE (V.)	SERVICE TIME TO 2.4 VOLTS (HRS)	REQUIRED SERVICE TIME TO 2.4 VOLTS (HRS)	MAX. CELL TEMP (°F)
DISCHARGE TEMP.: +130°F						
1	2.99	2.78	2.83	37.3	30	134
23	2.99	2.79	2.84	35.6	30	135
24	2.97	2.78	2.84	33.9	30	136
38	2.98	2.78	2.84	31.7	30	137
76	2.99	2.78	2.83	37.3	30	134
21	2.97	2.79	2.84	36.8	30	137
28	2.97	2.79	2.83	35.0	30	135
30	2.98	2.78	2.84	34.2	30	135
58	2.97	2.79	2.84	36.2	30	135
74	2.98	2.77	2.83	30.7	30	136
DISCHARGE TEMP.: +160°F						
12	2.96	2.79	2.84	30.7	30	169
32	2.97	2.80	2.85	30.5	30	167
42	2.98	2.80	2.85	31.2	30	168
54	2.97	2.79	2.84	30.2	30	166
70	2.96	2.80	2.85	31.8	30	169
5	2.97	2.80	2.85	32.5	30	170
37	2.97	2.81	2.86	34.5	30	167
53	2.97	2.79	2.84	31.2	30	170
62	2.98	2.80	2.85	30.2	30	171
88	2.97	2.80	2.85	34.8	30	167
DISCHARGE TEMP.: +70°F						
20	2.98	2.76	2.84	36.6	30	78
29	2.98	2.75	2.83	36.1	30	77
49	2.98	2.76	2.83	34.9	30	79
75	2.98	2.76	2.84	34.4	30	75
3	2.99	2.75	2.83	35.8	30	77
43	2.99	2.75	2.83	37.2	30	77
59	2.98	2.76	2.84	36.0	30	78
87	2.99	2.76	2.84	36.8	30	76
89	2.99	2.76	2.83	36.2	30	78

TABLE 4

CELL QUALIFICATION TEST PHASE (CONT.)

CELL S/N	OCV (VOLTS)	AVERAGE OUTPUT VOLTAGE @8Ω PULSE (VOLTS)	AVERAGE OUTPUT VOLTAGE @41.4Ω PULSE(V)	SERVICE TIME TO 2.4 VOLTS (HRS)	REQUIRED SERVICE TIME TO 2.4 VOLTS (HRS)	MAX. CELL TEMP. (°F)
DISCHARGE TEMP. : -40°F.						
33	3.02	2.48	2.62	21.7	10	-31
45	3.01	2.47	2.63	20.8	10	-29
47	3.02	2.49	2.63	19.6	10	-33
56	3.02	2.49	2.63	21.5	10	-32
92	3.02	2.50	2.64	22.4	10	-34
11	3.01	2.48	2.64	22.0	10	-29
40	3.02	2.47	2.62	21.8	10	-29
50	3.01	2.48	2.63	21.7	10	-33
65	3.01	2.48	2.63	18.5	10	-30
73	2.99	2.47	2.63	22.9	10	-35

TABLE 4 (Cont'd)

CELL QUALIFICATION TEST PHASE

CELL TYPE: BA-5588/U
TEST: CAPACITY
STORAGE HISTORY: 30 DAYS AT +160°F
DISCHARGE PROFILE: 8 OHMS, 1 MINUTE
41.4 OHMS, 9 MINUTES

DISCHARGE TEMP.: -40°F

CELL S/N	PULSE NO.	VOLTAGE @100 MS 8 OHMS	VOLTAGE @41.4 OHMS	CELL S/N	PULSE NO.	VOLTAGE @100MS 8 OHMS	VOLTAGE @41.4 OHMS
33	1	1.92	2.44	33	2	2.13	2.49
45	1	1.90	2.45	45	2	2.14	2.52
47	1	1.98	2.47	47	2	2.19	2.53
56	1	2.04	2.46	56	2	2.17	2.50
92	1	2.00	2.48	92	2	2.23	2.53
11	1	2.04	2.46	11	2	2.22	2.51
40	1	1.88	2.44	40	2	2.14	2.50
50	1	2.01	2.48	50	2	2.18	2.51
65	1	1.96	2.46	65	2	2.20	2.52
73	1	2.08	2.49	73	2	2.24	2.53
33	3	2.27	2.54	33	4	2.31	2.57
45	3	2.29	2.56	45	4	2.33	2.59
47	3	2.33	2.56	47	4	2.36	2.59
56	3	2.30	2.55	56	4	2.34	2.58
92	3	2.31	2.57	92	4	2.34	2.58
11	3	2.35	2.56	11	4	2.36	2.58
40	3	2.25	2.53	40	4	2.29	2.56
50	3	2.29	2.56	50	4	2.31	2.60
65	3	2.34	2.57	65	4	2.37	2.61
73	3	2.35	2.58	73	4	2.38	2.61
33	5	2.34	2.59	33	6	2.37	2.61
45	5	2.36	2.61	45	6	2.38	2.62
47	5	2.38	2.61	47	6	2.39	2.61
56	5	2.37	2.60	56	6	2.39	2.61
92	5	2.37	2.60	92	6	2.40	2.61
11	5	2.41	2.60	11	6	2.43	2.62
40	5	2.32	2.58	40	6	2.35	2.60
50	5	2.35	2.61	50	6	2.37	2.62
65	5	2.39	2.61	65	6	2.41	2.62
73	5	2.40	2.62	73	6	2.42	2.62

TABLE 5

CELL S.N	PULSE NO.	VOLTAGE @100MS 8 OHMS	VOLTAGE @41.4 OHMS	CELL S/N	PULSE NO.	VOLTAGE @100MS 8OHMS	VOLTAGE @41.4 OHMS
33	7	2.39	2.62	33	8	2.40	2.62
45	7	2.40	2.62	45	8	2.41	2.63
47	7	2.41	2.62	47	8	2.42	2.62
56	7	2.40	2.62	56	8	2.41	2.63
92	7	2.41	2.62	92	8	2.42	2.63
11	7	2.44	2.63	11	8	2.45	2.64
40	7	2.38	2.61	40	8	2.40	2.61
50	7	2.40	2.63	50	8	2.41	2.63
65	7	2.43	2.63	65	8	2.43	2.63
73	7	2.43	2.64	73	8	2.44	2.64

TABLE 5 (Cont'd)

CELL QUALIFICATION TEST PHASE
CELL TYPE: BA-5588/U
TEST: FORCED DISCHARGE
STORAGE HISTORY: 30 DAYS AT +160°F
DISCHARGE TEMPERATURE: +70°F
DISCHARGE CURRENT: 0.5 AMP.

CELL S/N	OCV (VOLTS)	TIME TO 2.0 (HR/MIN)	TIME TO 0.0V (HR/MIN)	MAX. CELL TEMP. (°F)	CELL CAP. (AMP-HRS)	OBSERVATIONS
10	2.99	5/53	6/00	141.0	2.9	SLIGHT BULGE
17	2.99	5/34	5/36	169.6	2.8	VENTED @ 7.2 HRS
51	2.99	6/22	6/24	120.2	3.2	SLIGHT BULGE
66	2.99	6/31	6/34	131.3	3.3	SLIGHT BULGE
78	2.99	5/50	5/53	118.2	2.9	NONE
19	3.00	6/16	6/22	134.6	3.1	NONE
31	2.99	7/10	7/14	126.4	3.6	NONE
39	2.98	6/42	6/48	132.6	3.4	SLIGHT BULGE
72	2.99	5/58	6/00	128.1	3.0	NONE
96	2.99	7/11	7/15	120.2	3.1	NONE

COMMENTS:

FORCE DISCHARGE WAS CONTINUED FOR SIXTEEN (16) HOURS. SEVERAL CELLS EXHIBITED SOME BULGING OF THE SAFETY VENT MECHANISM AS NOTED. S/N 17 SAFELY VENTED @ 7.2 HOURS INTO THE DISCHARGE.

TABLE 6

8. BATTERY FABRICATION PHASE PAPER JACKET

The specified test program was performed to provide the following:

- Evaluation of battery performance under the specified resistive load discharge profile at various temperatures after thirty (30) days storage at +160°F.

- Demonstration of battery safety under specified abusive test environments.

Ninety (90) batteries were fabricated during this phase of the development program utilizing a paper jacket case construction. Fifty (50) batteries were forwarded to ERADCOM for inspection and evaluation in accordance with CLIN 0001. The remaining forty (40) batteries were subjected to the following tests:

8.1 Visual/Mechanical Examination

Battery open circuit voltage (OCV), closed circuit voltage (CCV) @ 15 ohms, 30 seconds and battery dimensions/weight were measured to demonstrate compliance with the specified requirements.

8.2 Environmental Tests

The batteries were subjected to the following environments in the sequence given:

- Temperature Shock - In accordance with MIL-STD-810C, Method 503.1, for five cycles.

- Shock - In accordance with MIL-STD-810C, Method 516.2, Procedure I, Curve 516.2-2 for ground equipment.

- Vibration - In accordance with MIL-STD-810C, Method 514.2, Equipment Category (h), Procedures X & XI, Fig. 514.2-7, Table 514.2-VII.

- Altitude - In accordance with MIL-STD-810C, Method 500.1, Procedure I (omit operation in Step 4).

POST ENVIRONMENTAL

Visual/Mechanical Examination

Battery open circuit voltage (OCV), closed circuit voltage (CCV) @ 15 ohms, 30 seconds and battery dimensions/weight were again measured after environmental exposure to demonstrate compliance with the specified requirements (information only).

8.3 DISCHARGE TESTS

High Temperature Storage

All batteries were subsequently stored at +160°F for thirty (30) days. Upon completion of the storage period, the batteries were removed and apportioned in random lots of ten (10) units and tested as follows:

Elevated Temperature Tests - Ten batteries were stored at +130°F for a minimum of eight (8) hours and discharged under the specified load profile at 130°F ± 3°F. The battery discharge was monitored for temperature and voltage to zero volts. The service life of each battery is thirty (30) hours minimum.

High Temperature Tests - Ten batteries were stored at 160°F ± 3°F for a minimum of eight (8) hours and discharged under the specified load profile at 160°F ± 3°F. The battery discharge was monitored for temperature and voltage to zero volts. The service life of each battery is thirty (30) hours minimum.

Low Temperature Tests - Ten batteries were stored at -40°F for a minimum of eight (8) hours and discharged under the specified load profile at -40°F. The battery discharge was continuously monitored to zero volts. The service life of each battery is ten (10) hours minimum.

Safety Test - The remaining ten batteries were subjected to a direct external short circuit of less than 0.1 ohms at +75°F until cell venting occurred (battery fuses were electrically by-passed). Time to cell venting and visual observations were recorded.

8.4 TEST RESULTS AND OBSERVATIONS

8.4.1 Visual/Mechanical Examination

The open circuit voltage (OCV), closed circuit voltage (CCV) @ 15 ohms, 30 seconds and battery dimensions/weight was measured to initially demonstrate compliance of the forty (40) batteries with the specified requirements. The results are summarized in Table 7. No evidence of battery failure was observed.

8.4.2 Environmental Tests

The results and observations of the following specified environmental tests are summarized in Stanford Technology Corporation, Test Report ST-2398-OOC dated 29 May 1980 (see Appendix C):

- Temperature Shock
- Mechanical Shock
- Vibration

All batteries successfully passed the above environmental tests.

All batteries were subjected to the Altitude Test as specified. The results are summarized in Appendix D. No electrolyte leakage or other adverse effects were observed during or after environmental exposure.

Post Environmental Visual/Mechanical Examination

The open circuit voltage (OCV) @ 15 ohms, 30 seconds and battery dimensions/weight were again measured after environmental exposure to determine the condition of the batteries (information only). The results are summarized in Table 8. No evidence of battery failure was observed.

BA-5588( )/U BATTERY
PAPER JACKET
QUALIFICATION TEST SUMMARY
INITIAL INSPECTION

BATTERY S/N	OCV (VOLTS)	CCV @15Ω, 30 SEC (VOLTS)	WEIGHT (GRAMS)	A-ACCEPT R-REJECT		
				LENGTH	WIDTH	HEIGHT
1	14.81	12.60	284.5	A	A	A
11	14.81	12.73	285.7	A	A	A
13	14.81	12.73	287.6	A	A	A
31	14.80	12.80	284.6	A	A	A
33	14.80	12.69	284.3	A	A	A
35	14.80	12.76	283.7	A	A	A
38	14.80	12.70	285.0	A	A	A
41	14.80	12.63	283.3	A	A	A
42	14.80	12.64	283.3	A	A	A
44	14.80	12.47	282.7	A	A	A
45	14.81	12.73	281.9	A	A	A
46	14.81	12.60	283.1	A	A	A
47	14.80	12.41	283.3	A	A	A
49	14.81	12.67	282.7	A	A	A
54	14.80	12.64	282.3	A	A	A
56	14.79	12.62	281.1	A	A	A
58	14.72	12.65	284.4	A	A	A
62	14.80	12.64	284.9	A	A	A
64	14.81	12.54	283.4	A	A	A
66	14.81	12.56	283.3	A	A	A
68	14.81	12.56	284.6	A	A	A
69	14.80	12.65	283.4	A	A	A
72	14.79	12.58	284.2	A	A	A
74	14.80	12.64	282.4	A	A	A
76	14.79	12.60	282.9	A	A	A
77	14.80	12.63	284.1	A	A	A
79	14.77	12.61	283.0	A	A	A
80	14.75	12.72	284.5	A	A	A
81	14.71	12.92	279.3	A	A	A
82	14.81	12.77	280.7	A	A	A
83	14.80	12.61	279.5	A	A	A
84	14.80	12.64	280.2	A	A	A
85	14.80	12.74	277.7	A	A	A
86	14.78	12.76	278.8	A	A	A
87	14.81	12.61	279.8	A	A	A
88	14.80	12.76	280.7	A	A	A
89	14.80	12.57	280.2	A	A	A
90	14.78	12.82	279.0	A	A	A
91	14.80	12.72	280.6	A	A	A
92	14.81	12.62	283.5	A	A	A
93	14.80	12.64	282.2	A	A	A

TABLE 7

BA-5588( )/U BATTERY
PAPER JACKET
QUALIFICATION TEST SUMMARY
POST ENVIRONMENTAL INSPECTION

BATTERY S/N	OCV (VOLTS)	CCV @15 Ω, 30 SEC. (VOLTS)	WEIGHT (GRAMS)	A-ACCEPT R-REJECT		
				LENGTH	WIDTH	HEIGHT
1	14.87	12.84	285.1	A	A	A
11	14.85	12.81	286.8	A	A	A
13	14.86	12.87	288.4	A	A	A
31	14.86	12.81	285.4	A	A	A
33	14.89	12.76	284.9	A	A	A
35	14.85	12.67	283.2	A	A	A
38	14.87	12.76	281.8	A	A	A
41	14.86	12.81	283.6	A	A	A
42	14.84	12.77	285.1	A	A	A
44	14.88	12.47	283.9	A	A	A
45	14.86	12.85	282.5	A	A	A
46	14.87	12.70	283.5	A	A	A
47	14.84	12.81	284.0	A	A	A
49	14.86	12.78	283.2	A	A	A
54	14.84	12.78	283.2	A	A	A
56	14.87	12.72	282.0	A	A	A
58	14.85	12.69	285.0	A	A	A
62	14.86	12.77	285.4	A	A	A
64	14.85	12.75	284.1	A	A	A
66	14.87	12.67	284.0	A	A	A
68	14.86	12.71	285.3	A	A	A
69	14.85	12.68	283.9	A	A	A
72	14.85	12.66	284.4	A	A	A
74	14.85	12.64	283.4	A	A	A
76	14.85	12.69	283.1	A	A	A
77	14.81	12.74	284.7	A	A	A
79	14.84	12.69	283.6	A	A	A
80	14.77	12.76	285.0	A	A	A
81	14.87	12.94	279.7	A	A	A
82	14.87	12.82	281.4	A	A	A
83	14.86	12.35	280.2	A	A	A
84	14.86	12.78	280.8	A	A	A
85	14.85	12.82	277.9	A	A	A
86	14.86	12.80	279.0	A	A	A
87	14.86	12.75	280.0	A	A	A
85	14.85	12.84	280.0	A	A	A
89	14.84	12.64	280.0	A	A	A
90	14.87	12.87	278.9	A	A	A
91	14.86	12.80	281.5	A	A	A
9[illegible]	14.81	12.75	283.6	A	A	A
[illegible]	14.84	12.67	282.2	A	A	A

TABLE 8

8.4.3 CAPACITY TESTS

Thirty (30) batteries were randomly selected from the units that had undergone environmental exposure and +160°F storage for thirty (30) days. Ten (10) batteries were discharged after stabilization for eight (8) hours at 160°F, +130°F and -40°F. Each battery was pulse discharged through 40 ohms for one (1) minute followed by 207 ohms for nine (9) minutes repeated continuously to zero volts. Battery output voltage and temperature was continuously monitored as specified. The capacity discharge results are shown in Table 9. No cell venting was observed during discharge to zero volts. The results show that the batteries successfully complied with all specified minimum service life requirements.

The minimum start-up voltage requirement of 12.0 volts within 0.1 seconds was not achieved during discharge at -40°F. The results indicate that an average of 7.4 cycles was required to attain a minimum operating voltage of 12.0 volts after battery storage at +160°F for thirty (30) days. A summary of operational battery voltage during the first nine (9) cycles of the -40°F discharge is shown in Table 10.

8.4.4 SAFETY TEST

The remaining ten batteries were subjected to a direct external short circuit of less than 0.1 ohms at +75°F (battery fuses were electrically by-passed). The results, as summarized in Table 11, showed that the batteries complied with all safety requirements of the Technical Guidelines, paragraph 2.3.3. No adverse effects were observed.

BATTERY QUALIFICATION TEST PHASE (PART I)

BATTERY TYPE: BA-5588/U
TEST: CAPACITY
STORAGE HISTORY: 30 DAYS AT +160°F
DISCHARGE PROFILE: 40 OHMS, 1 MINUTE
207 OHMS, 9 MINUTES

BATTERY S/N	OCV (VOLTS)	AVERAGE OUTPUT VOLTAGE @40Ω PULSE (VOLTS)	AVERAGE OUTPUT VOLTAGE @207Ω PULSE (V)	SERVICE TIME TO 12.0 VOLTS (HRS)	REQUIRED SERVICE TIME TO 12.0 VOLTS (HRS)	MAX. BATT. TEMP. (°F)
DISCHARGE TEMP.: +130°F						
41	14.82	13.9	14.2	31.8	30	138
91	14.83	13.9	14.2	33.2	30	136
13	14.82	13.9	14.2	34.5	30	138
77	14.82	13.9	14.2	32.8	30	135
49	14.84	13.9	14.2	33.6	30	137
11	14.86	13.9	14.2	30.1	30	140
1	14.87	13.9	14.2	31.1	30	137
85	14.83	13.9	14.2	32.3	30	139
84	14.85	13.9	14.2	32.2	30	136
45	14.85	13.9	14.2	32.7	30	138
DISCHARGE TEMP.: +160°F						
54	14.82	14.0	14.3	33.4	30	171
92	14.82	14.0	14.3	32.4	30	171
47	14.80	13.9	14.2	30.6	30	174
66	14.83	14.0	14.3	31.3	30	172
68	14.81	14.0	14.3	36.5	30	169
31	14.82	14.0	14.3	34.8	30	170
56	14.83	14.0	14.3	32.1	30	176
62	14.83	14.0	14.3	33.0	30	168
79	14.83	14.0	14.3	31.9	30	178
81	14.81	14.0	14.3	32.8	30	170
DISCHARGE TEMP. -40°F						
64	15.25	12.4	13.2	18.8	10	-26
76	15.28	12.3	13.1	17.0	10	-28
82	15.28	12.3	13.1	17.5	10	-25
74	15.30	12.3	13.1	16.2	10	-32
72	15.26	12.3	13.2	18.0	10	-26
88	15.30	12.3	13.2	18.5	10	-30
89	15.28	12.2	13.0	15.5	10	-19
90	15.29	12.4	13.2	21.8	10	-35
38	15.25	12.3	13.2	21.0	10	-30
46	15.27	12.4	13.2	19.8	10	-30

TABLE 9

BATTERY QUALIFICATION TEST PHASE (PART I)
BATTERY TYPE: BA-5588/U
TEST: CAPACITY
STORAGE HISTORY: 30 DAYS AT +160°F
DISCHARGE PROFILE: 40 OHMS, 1 MINUTE
207 OHMS, 9 MINUTES
DISCHARGE TEMP.: -40°F

BATT. S/N	PULSE NO.	VOLTAGE @ 100 MS 40 OHMS	VOLTAGE @ 207 OHMS	BATT. S/N	PULSE NO.	VOLTAGE @ 100 MS 40 OHMS	VOLTAGE @ 207 OHMS
64	1	9.8	12.2	64	2	10.6	12.5
76	1	8.9	12.0	76	2	10.3	12.3
82	1	10.4	12.3	82	2	11.0	12.5
74	1	9.4	12.0	74	2	10.4	12.3
72	1	10.0	12.1	72	2	10.5	12.4
88	1	10.2	12.2	88	2	10.8	12.5
89	1	8.8	12.2	89	2	10.5	12.4
90	1	9.6	12.2	90	2	10.2	12.4
38	1	9 2	12.1	38	2	10.7	12.3
46	1	9.0	12.2	46	2	10.7	12.5
64	3	11.1	12.6	64	4	11.5	12.7
76	3	10.8	12.4	76	4	11.2	12.5
82	3	11.5	12.7	82	4	11.8	12.8
74	3	10.9	12.4	74	4	11.3	12.5
72	3	11.0	12.5	72	4	11.4	12.5
88	3	11.4	12.6	88	4	11.7	12.7
89	3	11.0	12.5	89	4	11.4	12.6
90	3	10.7	12.5	90	4	11.1	12.5
38	3	11.3	12.4	38	4	11.6	12.5
46	3	11.3	12.5	46	4	11.7	12.6
64	5	11.7	12.8	64	6	11.9	12.9
76	5	11.4	12.7	76	6	11.6	12.8
82	5	12.0	12.9	82	6	12.1	13.0
74	5	11.6	12.6	74	6	11.7	12.8
72	5	11.6	12.6	72	6	11.8	12.8
88	5	11.8	12.7	88	6	12.0	12.9
89	5	11.6	12.7	89	6	11.8	12.9
90	5	11.4	12.6	90	6	11.6	12.8
38	5	11.8	12.6	38	6	11.9	12.8
46	5	11.7	12.7	46	6	11.9	12.9

TABLE 10

BATT. S/N	PULSE NO.	VOLTAGE @ 100 MS 41 OHMS	VOLTAGE @ 207 OHMS	BATT S/N	PULSE NO.	VOLTAGE @100 MS 41 OHMS	VOLTAGE @ 207 OHMS
64	7	12.0	13.0	64	8	12.0	13.0
76	7	11.8	12.9	76	8	11.9	13.0
82	7	12.2	13.1	82	8	12.2	13.1
74	7	11.9	12.9	74	8	12.0	13.0
72	7	11.9	13.0	72	8	12.0	13.1
88	7	12.0	13.0	88	8	12.1	13.0
89	7	11.9	12.9	89	8	12.0	12.9
90	7	11.8	12.9	90	8	11.9	13.0
38	7	12.0	12.9	38	8	12.0	13.0
46	7	12.0	13.0	46	8	12.0	13.0
64	9	12.1	13.1				
76	9	12.0	13.0				
82	9	12.3	13.1				
74	9	12.0	13.0				
72	9	12.0	13.1				
88	9	12.1	13.1				
89	9	12.1	13.0				
90	9	12.0	13.0				
38	9	12.1	13.0				
46	9	12.1	13.1				

TABLE 10 (Cont'd)

BATTERY QUALIFICATION TEST PHASE (PART I)
BATTERY TYPE: BA-5588/U
TEST: SHORT CIRCUIT (<0.1 OHM)
STORAGE HISTORY: 30 DAYS AT +160°F
TEST TEMPERATURE: +70°F

BATTERY S/N	OCV (VOLTS)	TIME TO INITIAL CELL VENTING (MIN./SEC.)	OBSERVATIONS
33	14.85	1/25	(1) CELL VENTED
86	14.85	0/55	(3) CELLS VENTED
87	14.84	1/55	(2) CELLS VENTED
80	14.88	1/20	(1) CELL VENTED
35	14.87	1/40	(1) CELL VENTED
42	14.87	1/50	(1) CELL VENTED
44	14.86	2/35	(2) CELLS VENTED
58	14.85	1/10	(1) CELL VENTED
69	14.88	2/05	(2) CELLS VENTED
83	14.88	1/45	(1) CELL VENTED

TABLE 11

8.4.5 CONCLUSIONS:

Electrical Performance

Battery capacity exceeded all minimum service requirements under the discharge load temperatures after storage at +160°F for thirty (30) days. An average of 7.4 load cycles (transmit/receive) were required to attain a minimum operational voltage of 12.0 volts under the 40 ohm resistive load (transmit mode) at -40°F. It should be noted that previous tests have indicated the ability of the battery to meet start-up voltage specifications at 0°F.

Safety Performance

All batteries performed satisfactorily under the specified abusive test environments in accordance with the requirements of the Technical Guidelines.

9. BATTERY FABRICATION PHASE - PLASTIC JACKET

In accordance with CLIN 0003 PCI fabricated and delivered to the government BA-5588 batteries in the plastic case housing.

10. CONCLUSIONS AND RECOMMENDATIONS

A lithium sulfur dioxide balanced cell design has been effected to meet the electrical physical and environmental requirements as specified in the Technical Guidelines. Five series cells have been used for the construction of batteries which have been tested versus the following requirements.

Capacity before and after storage at 160°F

Start-up voltage at -40°F

Forced discharge, short circuit, temperature shock, shock, vibration and altitude.

The battery satisfied all of the electrical, physical and environmental requirements. A final battery design incorporating a plastic case was fabricated and 500 batteries were delivered to the government.

The studies performed indicated that the 100 ms, -40°F start-up requirement was beyond the capabilities of the system. It is recommended that the subject specification be modified to allow a less severe start-up requirement.

11. ACKNOWLEDGEMENT

The helpful suggestions and cooperation of Mr. John Christopulos of U.S. Army ERADCOM are gratefully acknowledged.

A P P E N D I X   A

STANFORD TECHNOLOGY CORP.

ENVIRONMENTAL TEST REPORT

ST - 2220

5 February 1980

STANFORD TECHNOLOGY CORP.
25 PARKER AVENUE • GLENBROOK, CONN. 06906
(212) 478-2010 (203) 348-4080

REPORT OF TESTS

on

LITHIUM CELLS
BA-5588

ENVIRONMENTAL TESTS

for

POWER CONVERSIONS, INC.
70 MACQUESTEN PARKWAY SO.
MT. VERNON, N.Y. 10550

February 5, 1980 ST-2220

SIGNATURES

FOR STANFORD TECHNOLOGY CORPORATION

Fred Esposito

Fred Esposito
Test Engineer

2·8·80
Date

Gerald T. Ciccone

Gerald T. Ciccone
Vice President

2-8-80
Date

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STANFORD TECHNOLOGY CORP.
TEST REPORT NO. ST-2220

ADMINISTRATIVE DATA

TEST CONDUCTED:	Temperature-Shock, Shock, Vibration
MANUFACTURER:	Power Conversions, Inc. 70 MacQuesten Parkway So. Mt. Vernon, NY 10550
MANUFACTURER'S TYPE OR MODEL NO.:	BA-5588 Cells
DRAWING, SPECIFICATION OR EXHIBIT:	Technical Guidelines for Primary Lithium Organic Electrolyte Battery BA-5588 ()/U
QUANTITY OF ITEMS TESTED:	Fifty (50) Cells S/N - See General Section
SECURITY CLASSIFICATION OF ITEMS:	Unclassified
DATE TEST COMPLETED:	February 5, 1980
DISPOSITION OF SPECIMENS:	Returned to Power Conversions
DATE OF TEST REPORT:	February 5, 1980
MANUFACTURER'S PURCHASE ORDER NO.:	9110
GOVT. CONT. NO.	N/A
ABSTRACT:	Refer to Test Results Section of this report.

FACTUAL DATA

1.0 TEST EQUIPMENT

1.1 Temperature Chamber
Tenney Engineering
Model: T15 UF-100240
Last calibration: September 15, 1979
Next calibration: March 15, 1980

1.2 High Temperature Chamber
Webber
Model: WF-15-100+350
Last calibration: November 3, 1979
Next calibration: May 3, 1980

1.3 Vibration Machine
MB Electronics
Model: C-10
Last calibration: September 16, 1979
Next calibration: March 16, 1980

1.4 Accelerometer
Columbia Research Laboratories
Model: 902
Last calibration: September 16, 1979
Next calibration: March 16, 1980

1.5 Band Pass Filter
Krohn-Hite
Model: 330N
Last calibration: October 3, 1979
Next calibration: April 3, 1980

1.6 Oscilloscope
Tektronix, Inc.
Model: 564 B
Last calibration: October 3, 1979
Next calibration: April 3, 1980

1.7 Integrator Amplifier
MB Electronics
Model: N-504
Last calibration: September 16, 1979
Next calibration: March 16, 1980

1.8 Shock Machine
Avco Research & Development Corp.
Model: SM-110
Calibration: Before each use

1.9 Temperature Bridge
Leeds & Northrup
Model: 86570
Last calibration: November 12, 1979
Next calibration: November 12, 1980

All instrumentation and equipment calibration conducted in accordance with and as defined in MIL-C-45662A, "Calibration Systems Requirements" and are traceable to the National Bureau of Standards.

2.0 TEST SEQUENCE AND COMPLETION DATES

2.1 Temperature Shock Test - Completed February 1, 1980

2.2 Shock Test - Completed February 4, 1980

2.3 Vibration Test - Completed February 5, 1980

GENERAL SECTION

Serial Numbers of the fifty (50) BA-5588 Cells tested.

76	39	65	89	74
21	40	31	72	59
1	69	56	10	50
62	88	58	28	3
92	37	32	5	47
11	70	87	3	45
38	73	54	24	42
19	66	23	20	12
75	96	51	78	43
49	30	29	17	53

3.0 TEST PROGRAM

3.1 Temperature Shock Test

3.1.1 Test Procedure

The Temperature Shock Test was conducted in accordance with MIL-STD-810C, Method 503.1, with the exception that five (5) cycles were performed and Step 9 was omitted.

Step 1 - The Cells were initially placed with a high temperature chamber which had been previously stabilized at +160°F, and maintained at this temperature for a period of not less than four (4) hours.

Step 2 - The Cells were then transferred within five (5) minutes to a low temperature chamber with an internal temperature of -70°F, and maintained at this temperature for a period of not less than four (4) hours.

At the completion of the low temperature period, the Cells were again transferred to the high temperature chamber within five (5) minutes.

Steps 1 and 2 constituted one (1) cycle of temperature shock. A total of five (5) cycles were performed.

At the completion of the entire Temperature Shock Test, and after stabilization at room ambient conditions, the Cells were visually examined for evidence of cracking, rupture, leakage, deterioration or corrosion.

3.1.2 Test Results

There was evidence of leakage to Cell Serial Number 69 as a result of this test. All other Cells exhibited no evidence of cracking, rupture or leakage.

3.2 Shock Test

3.2.1 Test Procedure

The Shock Test was conducted in accordance with MIL-STD-810C, Method 516.2, Procedure I, Figure 516.2-2, for ground equipment.

The Cells were securely fastened to the table of a shock machine and subjected to a total of eighteen (18) shock impacts. Each shock pulse approximated a half sine wave having a peak amplitude of 30 g's and a nominal time duration of eleven (11) milliseconds. Three (3) shocks were applied in each direction along each of three (3) mutually perpendicular axes.

At the completion of the Shock Test, the Cells were visually examined for evidence of physical damage or leakage.

3.2.2 Test Results

There was no visual evidence of physical damage or leakage as a result of this test. Serial Number 69 was not tested.

3.2 Vibration Test

3.2.1 Test Procedure

The Vibration Test was conducted in accordance with MIL-STD-810C, Method 514.2, Procedure X, Equipment E, Curve AW, non-operating.

The Cells were securely fastened to the table of a vibration machine and subjected to the following conditions.

The Cells were subjected to sinusoidal cycling at a logarithmic rate between the frequency limits and at the vibratory acceleration levels specified in Table I, for a period of eighty-four (84) minutes in each of the three (3) mutually perpendicular axes. No resonances were observed.

TABLE I

VIBRATION TEST LEVELS

Frequency (Hz)	Displacement/ Acceleration
5-200	1.5 g pk

At the completion of each axis of vibration, the Cells were visually examined for evidence of physical damage or leakage.

3.2.2 Test Results

There was no visual evidence of physical damage or leakage as a result of this test. Serial Number 69 was not tested. The Cells were returned to Power Conversions, Inc. for evaluation.

APPENDIX

Test Data and Photograph

REPORT NO. ST-2220

STANFORD TECHNOLOGY CORP.

CONVERSION POWER

TEST DATA SHEET

Test Condition +160°F + -70°F Date ______ Job. No. ______

Specification ______ Para. No. ______ Test Operator ______

Test Item ______ Part No. ______ Approved by ______

S/N							
76	37	51	50				
21	70	29	3				
1	73	89	47				
62	66	72	45				
92	96	10	42				
11	30	28	12				
38	65	5	43				
19	31	3	53				
75	56	24					
49	58	20					
39	32	78					
40	87	17					
69	54	74					
88	23	59					

Post Thermal Shock - S/N 69 Leakage noted.

TYPICAL SHOCK PULSE PHOTOGRAPH

Calibration

10 g's/division - vertical
2 ms/division - horizontal

A P P E N D I X B

ALTITUDE TEST RESULTS

BA-5588/U CELLS

Power Conversion, Inc.
Mount Vernon, NY 10550

February 1980

ALTITUDE TEST

BA-5588/U CELL

12 February 1980

1.0 SCOPE - Forty nine (49) cells were subjected to the specified altitude test in accordance with paragraph 2.5.1.4 of the BA-5588/U Technical Guidelines dated 3 February 1978.

2.0 TEST PROCEDURE - The altitude test was performed in accordance with MIL-STD-810C, Method 500, Procedure I.

The cells were placed non-operating within an altitude chamber while at room ambient conditions. The chamber was sealed and the internal pressure reduced to approximately 5.54 inches Hg. simulating an altitude of 40,000 feet. These environmental conditions were monitored for a period of one (1) hour.

At the completion of this period, the chamber pressure was adjusted to room ambient conditions. After stabilization, the cells were visually examined for evidence of electrolyte leakage, physical deterioration or other adverse effects.

3.0 TEST RESULTS - There was no evidence of electrolyte leakage, physical deterioration or other adverse effects as a result of this test.

APPENDIX C

STANFORD TECHNOLOGY CORP.

ENVORIMONMENTAL TEST REPORT

ST-2398-OOC

29 May 1980

STANFORD TECHNOLOGY CORP.
25 PARKER AVENUE • GLENBROOK, CONN. 06906
(212) 478-2010 (203) 348-4080

REPORT OF TESTS

on

LITHIUM CELLS
BA-5588/U

ENVIRONMENTAL TESTS

FOR

POWER CONVERSION, INC.
70 MACQUESTEN PARKWAY SO.
MT. VERNON, N.Y. 10550

May 29, 1980

ST-2398-00C

SIGNATURES

FOR STANFORD TECHNOLOGY CORPORATION

Harold T. Dennis
Harold T. Dennis
Senior Project Engineer

6-2-80
Date

Gerald T. Ciccone
Vice President

Date

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STANFORD TECHNOLOGY CORP.
TEST REPORT NO. ST-2398-00C

ADMINISTRATIVE DATA

TEST CONDUCTED:	Temperature-Shock, Shock, Vibration
MANUFACTURER:	Power Conversions, Inc. 70 MacQuesten Parkway So. Mt. Vernon, NY 10550
MANUFACTURER'S TYPE OR MODEL NO.:	BA-5588/U Cells
DRAWING, SPECIFICATION OR EXHIBIT:	Technical Guidelines for Primary Lithium Organic Electrolyte Battery BA-5588()/U, dated 2/3/78
QUANTITY OF ITEMS TESTED:	Forty-one (41) Cells S/N - See Table I
SECURITY CLASSIFICATION OF ITEMS:	Unclassified
DATE TEST COMPLETED:	May 29, 1980
DISPOSITION OF SPECIMENS:	Returned to Power Conversions
DATE OF TEST REPORT:	May 29, 1980
MANUFACTURER'S PURCHASE ORDER NO.:	9724
GOVT. CONT. NO.	N/A
ABSTRACT:	Refer to Test Results Section of this report.

TABLE I

Identification of Test Units

Forty-one (41) Batteries, 15 volts
Lithium-Organic EA 5588 ( )/U
Contract No. DAAK20-79-C-0260

Serial Numbers:

66, 74, 79, 58, 76, 92, 93, 91, 82, 41, 54, 42, 80, 46, 72, 56, 83, 62, 11, 64, 1, 31, 35, 77, 38, 89, 87, 68, 86, 69, 49, 33, 88, 47, 90, 44, 84, 81, 45, 13, 85

FACTUAL DATA

1.0 TEST EQUIPMENT

1.1 Temperature Chamber
Tenney Engineering
Model: T15 UF-100240
Last Calibration: March 15, 1980
Next Calibration: September 5, 1980

1.2 High Temperature Chamber
Webber Eng.
Model: WF-15-100+350
Last Calibration: May 3, 1980
Next Calibration: November 3, 1980

1.3 Vibration Machine
MB Electronics
Model: C-10
Last Calibration: March 16, 1980
Next Calibration: September 16, 1980

1.4 Accelerometer
Columbia Research Laboratories
Model: 902
Last Calibration: January 5, 1980
Next Calibration: July 5, 1980

1.5 Band Pass Filter
Krohn-Hite
Model: 330N
Last Calibration: October 3, 1979
Next Calibration: October 3, 1980

1.6 Oscilloscope
Tektronix, Inc.
Model: 564B
Last Calibration: March 24, 1980
Next Calibration: September 24, 1980

1.7 Integrator Amplifier
MB Electronics
Model: N-504
Last Calibration: March 16, 1980
Next Calibration: September 16, 1980

1.8 Shock Machine
Avco Research & Development Corp.
Model: SM-110
Calibration: Before each use.

1.9 Temperature Bridge
Leeds & Northrup
Model: 8693
Last Calibration: May 7, 1980
Next Calibration: November 7, 1980

All instrumentation and equipment calibration conducted in accordance with and as defined in MIL-C-45662A, "Calibration Systems Requirements" and are traceable to the National Bureau of Standards.

2.0 TEST SEQUENCE AND COMPLETION DATES

2.1 Temperature Shock Test - Completed May 22, 1980

2.2 Shock Test - Completed May 28, 1980

2.3 Vibration Test - Completed May 29, 1980

3.0 TEST PROGRAM

3.1 Temperature Shock Test

3.1.1 Test Procedure

The Temperature-Shock Test was conducted in accordance with MIL-STD-810C, Method 503.1, with the exception that five (5) cycles were performed and Step 9 was omitted.

Step 1 - The Cells were initially placed within a high temperature chamber which had been previously stabilized at +160°F, and maintained at this temperature for a period of not less than four (4) hours.

Step 2 - The Cells were then transferred within five (5) minutes to a low temperature chamber with an internal temperature of -70°F, and maintained at this temperature for a period of not less than four (4) hours.

At the completion of the low temperature period, the Cells were again transferred to the high temperature chamber within five (5) minutes.

Steps 1 and 2 constituted one (1) cycle of temperature shock. A total of five (5) cycles were performed.

At the completion of the entire Temperature-Shock Test, and after stabilization at room ambient conditions, the Cells were visually examined for evidence of cracking, rupture, leakage, deterioration or corrosion.

3.1.2 Test Results

All Cells exhibited no evidence of cracking, rupture or leakage.

3.2 Shock Test

3.2.1 Test Procedure

The Shock Test was conducted in accordance with MIL-STD-810C, Method 516.2, Procedure I, Figure 516.2-2, for ground equipment.

The Cells were securely fastened to the table of a shock machine and subjected to a total of eighteen (18) shock impacts. Each shock pulse approximated a half sine wave having a peak amplitude of 30 g's and a nominal time duration of eleven (11) milliseconds. Three (3) shocks were applied in each direction along each of the three (3) mutually perpendicular axes.

At the completion of the Shock Test, the Cells were visually examined for evidence of physical damage or leakage.

3.2.2 Test Results

There was no visual evidence of physical damage or leakage as a result of this test.

3.3 Vibration Test

3.3.1 Test Procedure

The Vibration Test was conducted in accordance with MIL-STD-810C, Method 514.2, Procedure X, Equipment E, Curve AW, non-operating.

The Cells were securely fastened to the table of a vibration machine and subjected to the following conditions.

The Cells were subjected to sinusoidal cycling at a logarithmic rate between the frequency limits and at the vibratory acceleration levels specified in Table I, for a period of eighty-four (84) minutes in each of the three (3) mutually perpendicular axes. No resonances were observed.

TABLE I

Vibration Test Levels

Frequency (Hz)	Displacement/ Acceleration
5-200	1.5 g pk.

At the completion of each axis of vibration, the Cells were visually examined for evidence of physical damage or leakage.

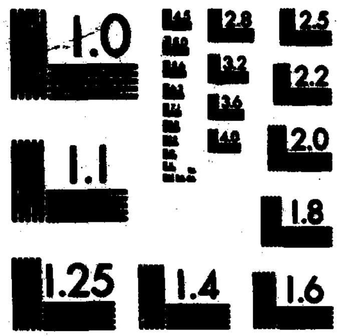
3.3.2 Test Results

There was no visual evidence of physical damage or leakage as a result of this test. The Cells were returned to Power Conversion, Inc. for evaluation.

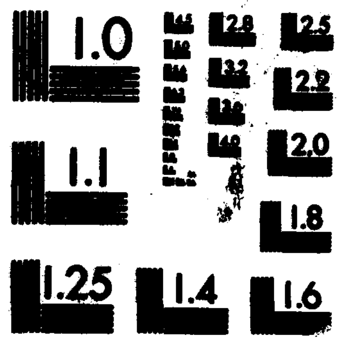
AD-A120 858 PRIMARY LITHIUM ORGANIC ELECTROLYTE BATTERY BA-5588(U) 2/2
POWER CONVERSION INC ELMWOOD PARK NJ M G ROSANSKY
JUL 82 DELET-TR-79-0260-F DAAK20-79-C-0260

UNCLASSIFIED F/G 10/3 NL

END



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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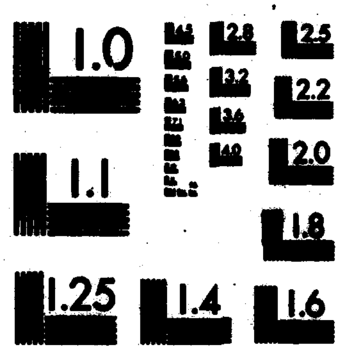

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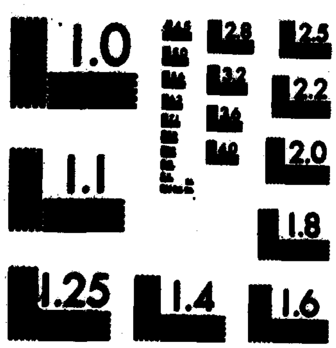

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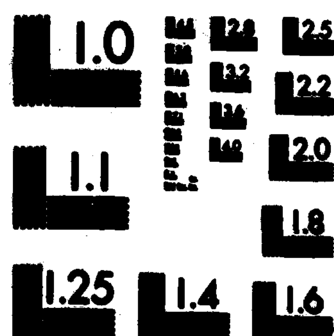

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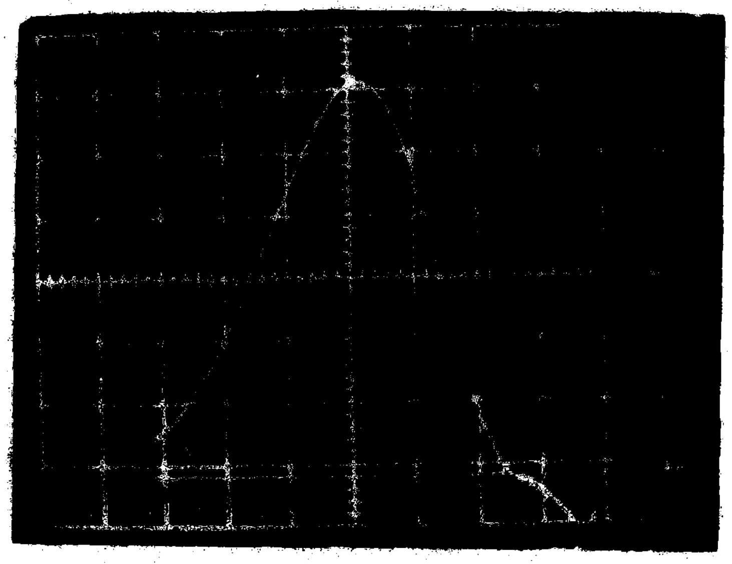

(30 g's, 11.0 ms, ½ sine)

Vertical Sensitivity: 5.0 g's/major division
Horizontal Sensitivity: 2.0 ms/major division

FIGURE 1

Calibration Photograph of Shock Pulse

APPENDIX D

ALTITUDE TEST RESULTS

BA-5588/U BATTERY

Power Conversion, Inc.
Mount Vernon, N.Y. 10550

3 June 1980

ALTITUDE TEST

BA-5588/U BATTERY
3 JUNE 1980

1.0 **SCOPE** - Forty (40) batteries were subjected to the specified altitude test in accordance with paragraph 2.5.1.4 of the BA-5588/U Technical Guidelines dated 3 February 1978.

2.0 **TEST PROCEDURE** - The altitude test was performed in accordance with MIL-STD-810C, Method 500, Procedure I.

The batteries were placed non-operating within an altitude chamber while at room ambient conditions. The chamber was sealed and the internal pressure reduced to approximately 5.54 inches Hg. simulating an altitude of 40,000 feet. These environmental conditions were monitored for a period of one (1) hour.

At the completion of this period, the chamber pressure was adjusted to room ambient conditions. After stabilization, the batteries were visually examined for evidence of electrolyte leakage, physical deterioration or other adverse effects.

3.0 **TEST RESULTS** - There was no evidence of electrolyte leakage, physical deterioration or other adverse effects as a result of this test.

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